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ARMSTRONG LABORATORY

THE DISTRIBUTION OF FLIGHT TRACKS ACROSS TAC VFR MILITARY TRAINING ROUTES

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FOR THE COMMANDER

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Noise measurements were performed on five VFR Military Training Routes. The objective was to determine the lateral distribution of operations across these routes, in order to validate or update the structure of the ROUTEMAP noise prediction model. It was found that distribution of operations about the centerline is Gaussian, as embodied in the current version of ROUTEMAP. It has been established from the current measurements that the standard deviation of flight tracks is generally 0.17 times the route width. This dispersion is due to a combination of (a) missions using a variety of nominal tracks and (b) the variation inherent in visual navigation. In situations where there is only one nominal track (route width less than 6 nautical miles, choke points, or specific local conditions), the standard deviation is one nautical mile. Recommendations are made for revisions to ROUTEMAP to incorporate these new results.

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1.0 INTRODUCTION

Low-altitude, high-speed training operations are routinely conducted by all Air Force flight operation commands. These operations are conducted on specially designated Military Training Routes (MTRs).* Routes are continually changed because of the need for variety, changing requirements of weapon systems and tactics, and encroachment on existing routes. Environmental assessments are required for new routes. A series of studies on MTR noise[1-4] has led to the ROUTEMAP model[5] which is currently used for these assessments.[6] The main objective of this study was to further support the previous measurement studies and to review (and modify, if necessary) the ROUTEMAP noise modeling program.[5]

Reference 1 contains an overview of MTR operations and identifies both short- and long-term research which are needed in order to support environmental assessments. Included in the short-term needs were measurements of noise on two MTRs: one operated by SAC and one by TAC,** the two dominant route users. SAC operates several dozen routes ranging in length up to 1,000 miles. TAC operates several hundred routes with lengths typically between 100 and 300 miles. Recommendations were also made for psychoacoustic research needed to understand the human effects of this type of noise environment, which is sporadic in nature and different from the urban airport/highway environment extensively studied for community response to noise.

Reference 2 contains the results of a measurement program on a SAC route. SAC operations are conducted on Instrument Flight Rule (IFR) routes (denoted IR), and involve point-to-point navigation using a variety of electronic aids. A key finding of Reference 2 was that aircraft tend to be near the centerline of the route, with deviation from the centerline being well described by a Gaussian distribution with a standard deviation of 0.45 nautical mile.*** The noise levels of individual

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* MTR operations take place under waivers to FAR 91.117 (Aircraft Speed), which normally limits speeds to 250 kt indicated airspeed below 10,000 feet MSL.

** As of 1 July 92, SAC and TAC have been reorganized into Air Combat Command (ACC).

*** Results of References 2 and 4 were presented in statute miles. This is inconsistent with the use of nautical miles for MTR descriptions and has proven to be a significant inconvenience. In the current study, results are presented in terms of nautical miles, and it is recommended that ROUTEMAP be modified to adopt this convention.

aircraft were found to be in good agreement with predictions from the Air Force's NOISEFILE data base. Because of the limited variety of aircraft types involved (almost all B-52 and B-1) and the centralized command and training structure of SAC operations, it was concluded that these results can be generalized to all SAC low-level routes. Reference 2 also contains anecdotal observations of residents' reactions to low-level flight operations.

Reference 4 contains results from a similar measurement program performed on two TAC routes. Most TAC operations are conducted under Visual Flight Rules (VFR) on VFR routes (denoted VR). Many different mission types are flown by TAC aircraft including ground attack, basic training, and others. There were two important findings in Reference 4. First was that when a route section had a single dominant track which the aircraft followed, the distribution of aircraft was well defined by a Gaussian distribution of standard deviation 1.1 nm.* Second, if multiple tracks occurred within a route section, the distribution of aircraft was well described by a Gaussian distribution with a standard deviation of about 2.2 nm.**

This report presents the results of similar measurements performed on five additional TAC routes. The first two routes were located in Arizona and were scheduled through Luke AFB. These routes were VR-1220 and VR-223, and both supported advanced student training operations. The third and fourth routes, VR-087 and VR-088, were located in South Carolina. These routes supported air-to-ground mission training for F-16s out of Shaw AFB. The final route, VR-1074, was located in North Carolina. This route supported night-attack missions for F-15s from Seymour Johnson AFB.

Noise measurements were taken using from 16 to 30 automatic noise monitors placed laterally across the route. Each time the noise level exceeded a preset threshold, the monitors recorded the maximum A-weighted sound level, the time and duration of the event, and the sound exposure level. These data were subsequently analyzed to determine the statistical distributions of maximum sound levels (and hence aircraft tracks) relative to the route centerline.

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* 1.25 statute miles.

** 2.5 statute miles.

The key findings of the current study are as follows:

- Noise levels from individual flyovers are in very good agreement with the noise level data base used by ROUTEMAP.
- Flight tracks are distributed across the route, with the distribution having a Gaussian form. This is the same result as in References 2 and 4.
- The standard deviation of flight tracks varies with route width. The relationship between standard deviation and width is presented, together with suggested rules for selecting appropriate values for various situations.

Section 2 of this report contains a description of current TAC low-level training operations. Section 3 contains a description of the five routes studied and the conduct of the field programs. Section 4 presents analysis of the data and the findings of the study are summarized in Section 5.

2.0 TAC LOW-LEVEL TRAINING OPERATIONS

2.1 Routes and Mission Profiles

The Tactical Air Command conducts high-speed, low-level training missions under visual flight rules. The objective of these missions (denoted air-to-ground) is to practice low-level, point-to-point navigation. Current procedures call for altitudes as low as 100 feet AGL and air speeds from 420 to 480 knots. TAC aircraft involved include F-4s, F-15s, and F-16s. Navy, Marine, Air National Guard, and Reserve units routinely fly similar missions on many of the same or similar routes. The operations are qualitatively similar to SAC low-level missions in that the aircraft are navigating to a destination, nominally following a series of predetermined navigation points. There are inherent differences from SAC operations due to the prevalence of visual flight rules for these routes: operations tend to be during daylight hours, and navigation points are not crossed with the same high degree of precision. Fighter aircraft also operate in multiple-ship formations, which can be over a mile wide. Most flights have two or four aircraft. A typical two-ship formation is line abreast, where the aircraft are even with each other and laterally separated by 6,000 to 8,000 feet. An alternative is for the second aircraft to fly in trail, 10,000 to 15,000 feet behind the leader. On occasion, two aircraft will fly in a close echelon, separated by a few hundred feet, but this is relatively uncommon. Four aircraft fly in box formation, consisting of two lines abreast with the second line following the first by 10,000 to 15,000 feet. The second line is usually offset about half the line width. Wide formations tend to change structure, then reform as they negotiate turns, mountain passes, ridges, etc.

Figure 1 shows a typical TAC route, VR-223 in southern Arizona. Shown are the centerline and edge boundaries. Also shown are candidate measurement sites which had been considered for measurements on this route.[7] Official route descriptions are published in the AP/1B booklet.[8] Figure 2 is the published description of VR-223 taken from Reference 8. The approach to primary entry point A is specified as 6,000 feet MSL (about 4,500 feet AGL), with the remainder clear for 500 feet AGL. Minimum published altitudes are based on obstacle clearance, and on many routes are 100 feet AGL or surface. Higher limits imposed by the command supersede these. While the route may be entered or exited at a number of points, it is typical to use the primary entry and exit. The route width

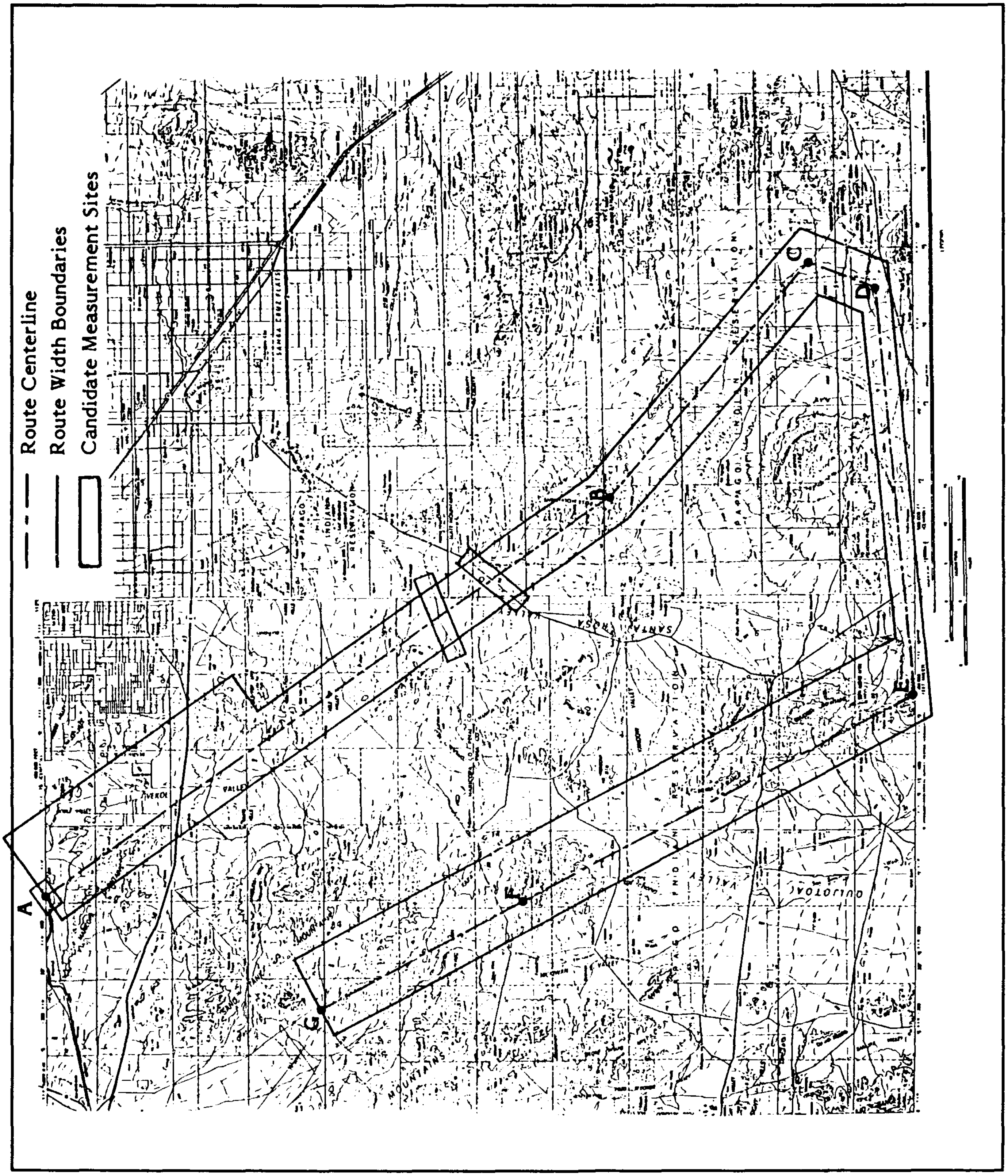

Figure 1. Low-Altitude TAC Route: VR-223.

Altitude Data	Pt	Fac/Rad/Dist	Lat/Long
As asgn to	A	ENI 274/50	39°22.0'N 124.°16.0'W
02 AGL B 15 AGL to	B	ENI 308/41	39°37.0'N 123°46.0'W
02 AGL B 15 AGL to	C	ENI 328/37	39°39.0'N 123°28.0'W
02 AGL B 30 AGL to	D	RBL 210/28	39°47.0'N 122°41.0'W
30 AGL B 80 MSL to	E	RBL 112/48	39°35.0'N 121°27.0'W
02 AGL B 30 AGL to	F	RNO 282/45	39°54.0'N 120°30.0'W
02 AGL B 15 AGL to	G	RNO 345/40	40°12.0'N 119°37.0'W
02 AGL B 15 AGL to	H	RNO 054/33	39°42.0'N 118°59.0'W
02 AGL B 15 AGL to	I	HZN 073/4	39°31.0'N 118°54.0'W

TERRAIN FOLLOWING OPERATIONS: Authorized entire route.

ROUTE WIDTH — 2 NM either side of centerline.

Special Operating Procedures:
(1) Pilots exiting at I must obtain target times in R-4803 from NAS Fallon Range Control prior to flying route.
(2) Pass north of Doyle between F and G.
(3) Alternate Entry: B.
(4) Alternate Exit: H.
(5) Tie-in FSS: Fresno (FAT).

FSS's Within 100 NM Radius:
MYV, ACV, RBL, LOL, UKI, OAK, CEC, SAC, SCK, RNO, SIY, TPH

VR-208

ORIGINATING/SCHEDULING ACTIVITY: COMLATWINGPAC NAS Lemoore, CA 93246-0022 AUTOVON 949-3631.

HOURS OF OPERATION: Continuous.

ROUTE DESCRIPTION:

Altitude Data	Pt	Fac/Rad/Dist	Lat/Long
As asgn to	A	OAL 180/45	37°17.0'N 118°03.0'W
02 AGL B 130 MSL to	B	OAL 142/36	37°27.0'N 117°30.0'W
02 AGL B 130 MSL to	C	TPH 189/22	37°42.0'N 117°14.0'W
02 AGL B 130 MSL to	D	TPH 266/10	38°04.0'N 117°14.0'W
02 AGL B 100 MSL to	E	MVA 039/48	39°01.0'N 117°11.0'W
02 AGL B 120 MSL to	F	MVA 022/72	39°24.0'N 116°57.0'W
02 AGL B 120 MSL to	G	HZN 087/53	39°18.0'N 117°53.0'W

TERRAIN FOLLOWING OPERATIONS: Authorized entire route.

ROUTE WIDTH — 10 NM either side of centerline.

Special Operating Procedures:
(1) Avoid airports along route by 2000' or 3 NM.
(2) Avoid unauthorized entry into R-4816 between F and G.
(3) Avoid Tonopah VORTAC at D by 7 NM.
(4) Tie-in FSS: Tonopah (TPH).
(5) Avoid overflight of the town of Goldfield (Pt C) by 3 NM or 1500' AGL.

FSS's Within 100 NM Radius:
EKO, ELY, LOL, TPH, LAS, FAT, RNO, BFL

VR-223

ORIGINATING ACTIVITY: Airspace Management 832 Air Division Luke AFB, AZ, 85309 AUTOVON 853-6067.

SCHEDULING ACTIVITY: 832 Air Division Scheduling (Advance scheduling) Luke AFB AZ 85309 AUTOVON 853-7653
Command Post 405 Tactical Training Wing (Same day scheduling) Luke AFB, AZ 85309 AUTOVON 853-6022.

HOURS OF OPERATION: Continuous.

ROUTE DESCRIPTION:

Altitude Data	Pt	Fac/Rad/Dist	Lat/Long
Enter at 05 AGL B			
60 MSL at	A	PHX 211/36	33°00.0'N 112°24.0'W
05 AGL B 60 MSL to	B	TUS 272/55	32°21.0'N 111°52.0'W
05 AGL B 80 MSL to	C	TUS 257/37	32°07.0'N 111°33.0'W
05 AGL B 80 MSL to	D	TUS 250/39	32°02.5'N 111°35.0'W
05 AGL B 90 MSL to	E	CZG 178/54	32°00.0'N 112°08.0'W
05 AGL B 90 MSL to	F	CZG 210/36	32°27.0'N 112°24.5'W
05 AGL B 90 MSL to	G	CZG 236/35	32°41.0'N 112°33.0'W

TERRAIN FOLLOWING OPERATIONS: Authorized A to E.

ROUTE WIDTH — 2 NM right and 5 NM left of centerline, A to 32°44'00"N 112°11'00"W; 2 NM *either side of centerline* 32°44'00"N 112°11'00"W to D; 1 NM either side of centerline, D to E; 2 NM left and 4 NM right of centerline, E to G.

Special Operating Procedures:
(1) Contact scheduling activity for route briefing.
(2) Turn radius based on 420 KIAS.
(3) Tie in FSS: Phoenix (PHX)- Contact prior to entry.
(4) Primary Entry: A. Alternate ENTRY: B, C, D, E.
(5) Primary Exit: G. Alternate Exit: B,C, D, E, F.
(6) Route flight checked to a minimum altitude of 500 feet AGL only.
(7) Scheduling this route does not automatically grant permission to enter R-2301E, R-2304 or R-2305. Obtain clearance to enter these restricted areas from scheduling activity when scheduling the route.
(8) Monitor 379.4 MHz from 20 NM past point A to point G-Latn training area.
(9) Report exit to Gila Bend Range operations on 272.1 MHz when planning use of R-2301E, R-2304 or R-2305.
(10) Avoid overflight of all towns/settlements/populated areas below 3000 feet vertically and /or 1 NM horizontally. Avoid VAYA CHIN 23 NM past point E by at least 3000 feet vertically and 2 NM horizontally. Minimum altitude 5000 feet MSL from 32°13'00"N, 112°16'00"W to 32°27'00"N, 112°24'00"W.
(11) Avoid overflight of all charted/uncontrolled Airports by at least 1500 feet vertically and/or 3 NM horizontally.
(12) CAUTION: Numerous other MTRs cross or are coincident with VR-223. See FLIP AP/1B, IFR/VFR wall planning charts, and appropriate sectional/Enroute Low Altitude Charts.

FSS's Within 100 NM Radius:
BLH, DUG, TUS, PRC, PHX, YUM,ONT

VR-225

ORIGINATING/SCHEDULING ACTIVITY: 474 TFW/DOO Nellis AFB, NV 89191 AUTOVON 682-2090.

HOURS OF OPERATION: Continuous.

ROUTE DESCRIPTION:

Altitude Data	Pt	Fac/Rad/Dist	Lat/Long
As assigned to	A	PHX 311/34	33°54.0'N 112°17.0'W
15 AGL B 75 MSL to	B	PHX 334/39	34°04.0'N 112°03.0'W
05 AGL B 95 MSL to	C	PHX 354/51	34°17.0'N 111°45.0'W
55 MSL B 95 MSL to	D	PHX 001/61	34°25.0'N 111°33.5'W
15 AGL B 95 MSL to	E	INW 193/13	34°52.0'N 110°55.0'W
05 AGL B 105 MSL to	F	INW 257/18	35°04.0'N 111°10.0'W
105 MSL B 125 MSL to	G	INW 267/43	35°12.0'N 111°39.0'W
105 MSL B 125 MSL to	H	DRK010/36	35°15.0'N 112°11.0'W
15 AGL B 105 MSL to	I	DRK319/41	35°19.0'N 112°52.0'W
05 AGL B 95 MSL to	J	DRK252/27	34°40.0'N 113°01.0'W
05 AGL B 75 MSL to	K	BXK 322/39	34°03.0'N 113°09.0'W
55 MSL B 75 MSL to	L	BXK 307/30	33°50.5'N 113°12.0'W
05 AGL B 55 MSL to	M	BXK 233/26	33°17.0'N 113°18.0'W
15 AGL B 55 MSL to	N	GBN 262/34	33°01.0'N 113°21.0'W
15 AGL B 35 MSL to	O	GBN 230/35	32°42.0'N 113°18.0'W

2-11

Figure 2. Route Description of VR-223, From Reference 8.

varies, based on clearance of known obstacles and avoidance of noise-sensitive areas such as population centers and recreational areas. Typical widths range from 4 to 20 nautical miles; segment D–E of VR-223 is 2 miles wide. There is no formal lateral constraint except to remain within the route boundaries. At the speeds involved and with visual navigation, events happen very quickly as the pilot watches for landmarks several miles ahead, so that the tendency is to remain within the center part of the corridor.

Prior to a mission a tentative flight plan is prepared by each pilot. This plan is sketched on a map containing the route outlines along with notes on headings, obstacles, and areas to avoid. Figure 3 shows one such mission plan for VR-087 in South Carolina. A path is drawn between navigation points within the boundaries of the MTR. These navigation points appear as circles in Figure 3 and usually correspond to prominent landmarks. In addition, the mission plan has one navigation point labeled with a square followed by a point labeled with a triangle. The square navigation point denotes a check point which orients the mission towards the simulated target labeled with the triangle.

Not every mission uses a unique flight plan; this depends on particular goals. For example, in student pilot training, emphasis is on aircraft handling. In that case, only the instructor pilot leading the flight will have a mission plan, and that will be a standard chart used repeatedly for that route.

2.2 Operations and Scheduling

The busiest TAC routes are scheduled for 2,000 to 3,000 sorties per year. Based on 200 flying days per year, there will be an average of 10 to 15 sorties (grouped in three to five missions) per day on these busy routes. Minimum headway between flights is 5 minutes, although the average time between flights is much greater. The rate of flights is comparable to that on SAC routes (average of five flights per day on the busiest routes[2]), and is comparably sporadic. Each flight is essentially an isolated event, so that there is no reason to expect mission profiles on busy routes to differ from those on lightly used ones. As was done for the previous route measurements,[2,4] the TAC routes selected for this study were busy ones for which relatively large amounts of data could be collected in a reasonable time.

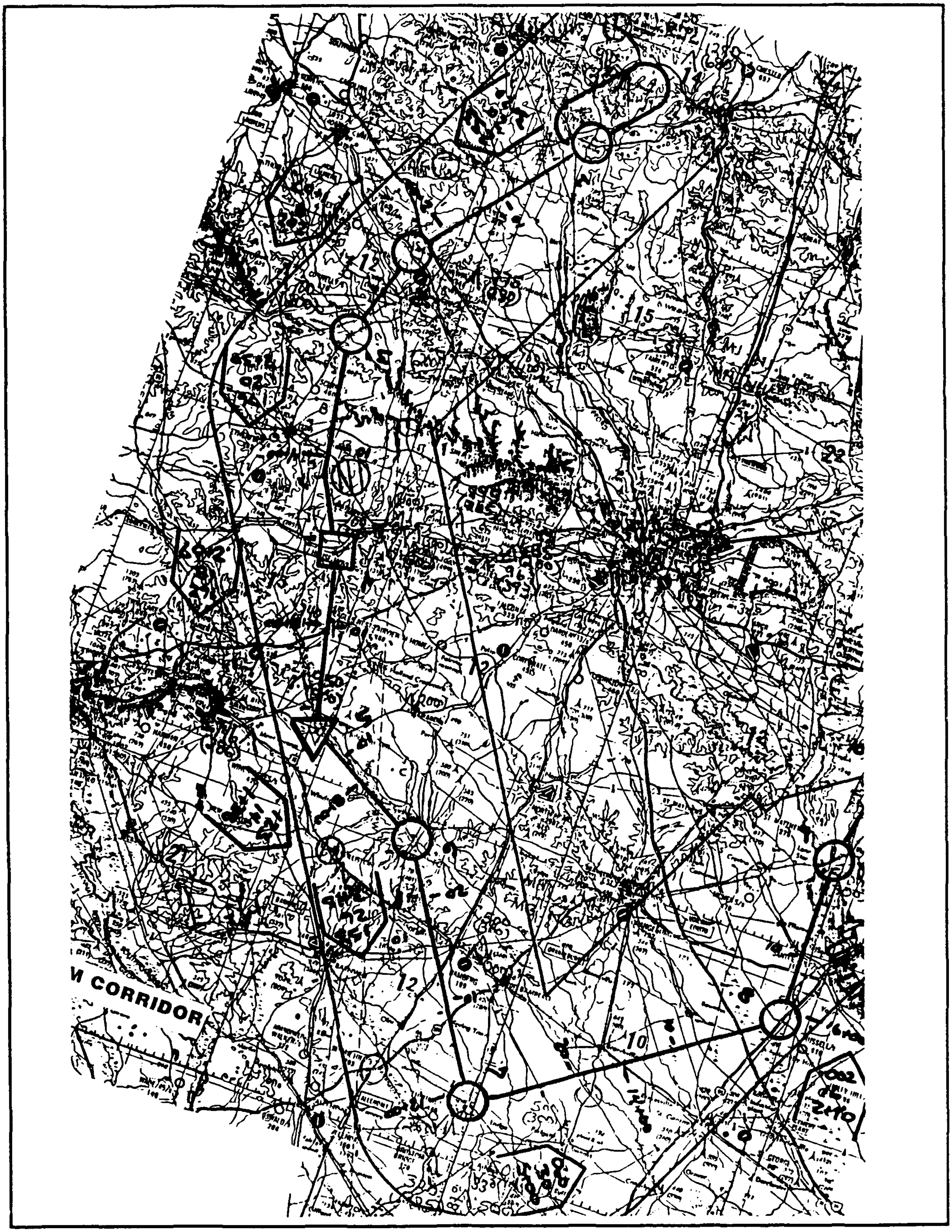

Figure 3. VR-088 Mission Plan.

Scheduled activity for TAC routes is decentralized, with responsibility handled by the primary route user. Route descriptions in the AP/1B booklet[8] identify the scheduling activity plus appropriate military or civil air traffic control. The purpose of scheduling is to avoid conflicts between users, without unreasonably restricting the flexibility and initiative implicit to tactical air operations. A secondary use of schedule information is that these data can be analyzed to assess the utilization of various routes, and thereby aid in airspace planning. This form of schedule data is of interest in the current project, but it must be kept in mind that available data are not collected for that purpose.

Scheduling is performed with various degrees of advance and short-term planning. Reservation of specific time slots for particular missions generally takes place the evening before or the morning of a mission. However, same-day scheduling can occur up to aircraft launch time. At some bases, where local weather changes rapidly, pilots may only schedule that they are doing a low-level mission, and select the route based on conditions after launch. Actual route entry times are usually within 15 minutes of scheduled times. Aircraft can also fly many routes without advance schedule by obtaining clearance from the appropriate air traffic control center. The schedule log will not reflect this unscheduled activity, nor will it account for mission cancellations. There are also occasional incidents of aircraft flying routes without schedule or clearance. Usually, these are aircraft at slower speeds (below 250 kts) under visual conditions, whose operations fall within FAR 91.117 (Aircraft Speed), and therefore do not need to schedule special use airspace.

Schedule data used in this study represents the records kept by the route operators. Data were collected after each flying day. They are therefore expected to include all scheduled missions which flew, and also include missions which were scheduled but cancelled.

3.0 FIELD PROGRAM

3.1 Site Selection

Measurement sites were selected on five MTRs based on the following criteria:

1. Two routes in a western desert area, and three in an eastern forested area. Differences in aircraft and/or operations were also desirable.

2. Areas of relatively flat terrain, to measure activity where altitudes would be lowest and with minimal site-specific constraints.

3. Existence of a reasonably accessible road crossing the route, suitable for deploying noise monitors.

4. High level of flight activity.

Sites meeting these criteria were found along VR-1220 and VR-223 in Arizona, VR-087 and VR-088 in South Carolina, and VR-1074 in North Carolina. Each of these routes is described in detail in the following sections.

3.1.1 VR-1220, Arizona

Figure 4 shows the section of VR-1220 between points F and G (F being the northern turn point) as defined in the AP/1B booklet.[8] This MTR is located west of Phoenix, Arizona. Operations on this route are advanced pilot training missions out of Luke AFB. On this section of the route aircraft travel from north to south. A suitable site for the measurement was found about 15 miles north of point G as shown in Figure 4. This site consisted of a dirt road, from Cunningham Pass to Cactus Plain, which provided service access to a power line through the area. The route is 10 nautical miles wide between points F and G and covers desert terrain. Flight is cleared down to 300 feet AGL.

For measurements on VR-1220, the noise monitors were chained to power line towers which provided good visual references for unit location. Thirty monitors were placed along the road spanning the width of the route. The ten

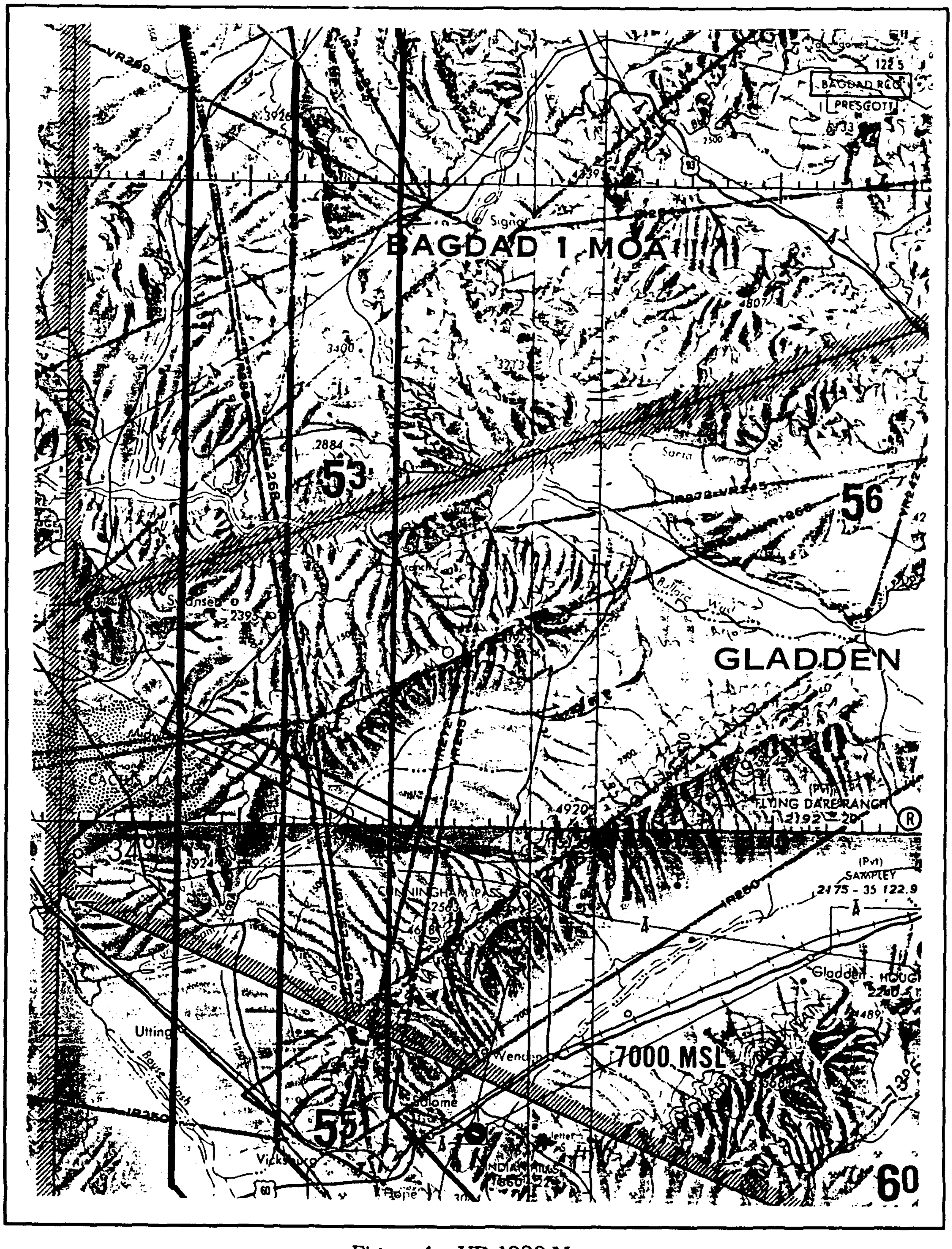

Figure 4. VR-1220 Map.

monitors which straddled the route centerline were separated by a one-quarter-mile interval. This interval progressively increased to a maximum of one mile between the last three monitors at either edge of the route. This interval arrangement maximized the density of monitors near the route centerline where most of the air traffic was expected.

As can be seen in Figure 4, there are several other MTRs which overlap parts of the measurement array. These include VR-245, VR-283, VR-1267, VR-1268, IR-214, and IR-272. The air traffic along these routes could have been recorded by the noise monitors. Schedule data for VR-245 was available which allowed missions on this route to be removed from the data. The other routes were identified as being lightly used.

Arrangements were made with the 832nd Air Division to obtain schedule information for the measurement period of 3 March 1991 to 31 March 1991 for VR-1220 and VR-245.

3.1.2 VR-223, Arizona

Figure 5 shows most of VR-223, which is located south of Phoenix, Arizona. Operations on this route are advanced pilot training missions out of Luke AFB. The measurement site selected for this route was located between points A and B of the route[8] as shown in Figure 5. Air traffic travels in a clockwise direction around the MTR. From point A to a point along the route near the measurement site the route is 7 nautical miles wide; 2 nautical miles left and 5 nautical miles right of the centerline. After this point the route boundaries are 2 nautical miles either side of the centerline. Flight is cleared down to 500 feet AGL between points A and B. The terrain below this section of the route was desert.

The measurement site, indicated in Figure 5, was along a dirt road through the Vekol Ranch. This is at the point where the route narrows from 7 to 4 nautical miles. The Tabletop Mountains obstruct the eastern quarter of the route, so this location is a choke point with an effective width of about 3 nautical miles. Sixteen monitors were deployed across this portion of the route, at 0.25 statute mile intervals, from 0.5 mile west of the western boundary to 1.5 miles east of the route centerline.

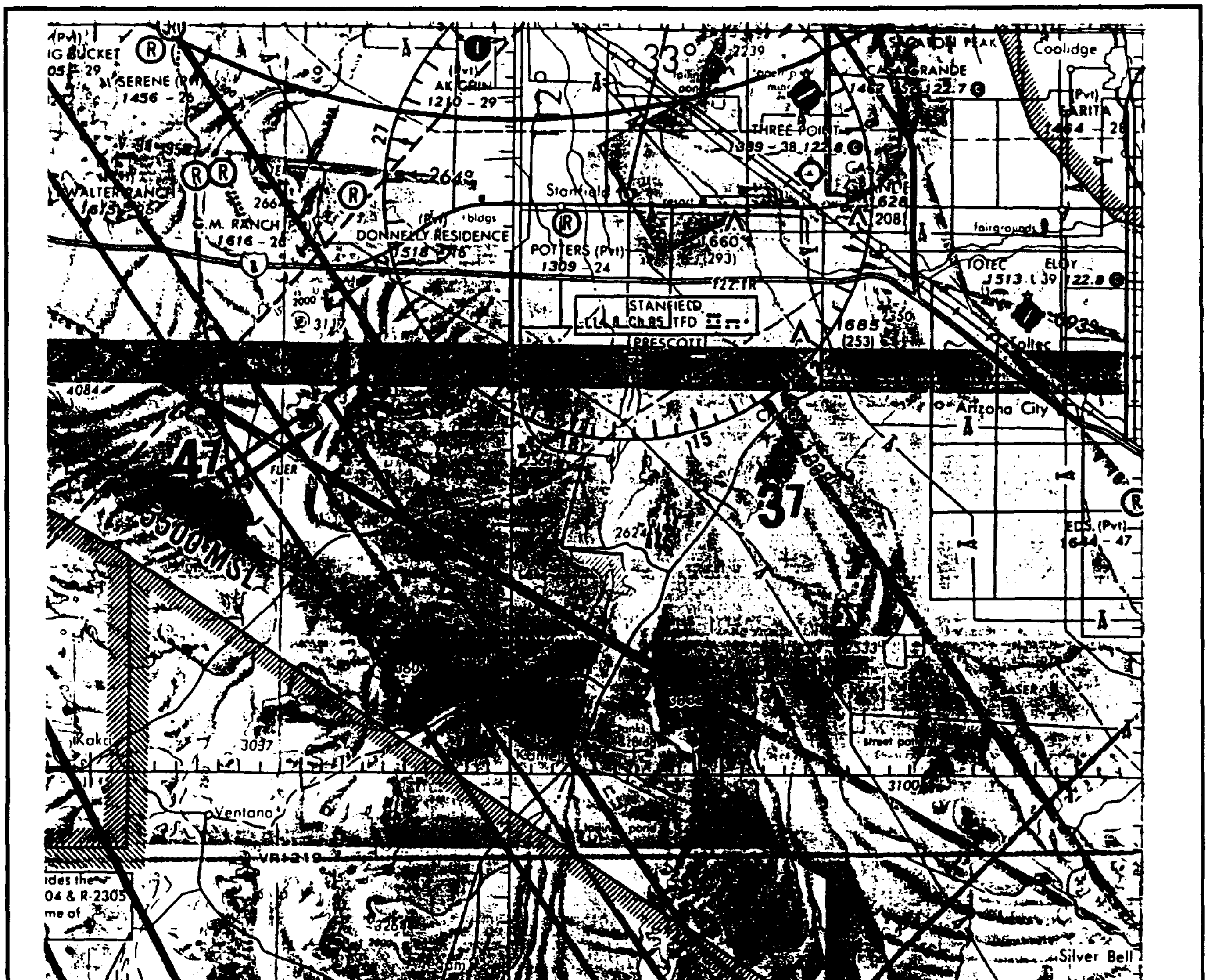

Figure 5. VR-223 Map.

Arrangements were made with the 832nd Air Division to obtain schedule information for this route. No other MTRs were in the vicinity of the measurement array.

3.1.3 VR-087, South Carolina

This route is located east of Sumter, South Carolina. Operations along this route consisted of ground attack readiness training by F-16s stationed at Shaw AFB. Figure 6 shows the leg of VR-87 between points E and F where operations travel west. This segment of the route is 16 nautical miles wide and flight is cleared down to 100 feet AGL. A suitable measurement site was located along a rural highway as depicted in Figure 6. The terrain under this leg of the route is rural forests and agricultural fields.

The measurement array was located along SC Route 527. Twenty-eight monitors were placed about 0.7 mile apart along the side of the road and were chained to telephone poles. This arrangement spanned the entire route, although the wide spacing did reduce the resolution of the noise measurements.

Arrangements were made with the 363rd Fighter Wing at Shaw AFB to obtain schedule information for the route.

3.1.4 VR-088, South Carolina

Operations along this route consisted mainly of ground attack readiness training by F-16s stationed at Shaw AFB. Figure 7 shows part of VR-88 between points C and G where operations travel southeast. The measurement site selected, as shown in Figure 7, was located just east of Aiken, South Carolina. The route along this leg is 20 nautical miles wide. Flight is cleared down to 300 feet AGL. The terrain under this leg is mostly rural forests and agricultural fields.

The measurement array was located along several rural roads, stretching from 8 miles east of Aiken, SC, through the town of New Holland, SC (under the route centerline), to the town of Fairview Crossroads, SC. Twenty-seven monitors were distributed across this route. The monitors within 3 miles of the route centerline were spaced 0.5 mile apart. Monitors beyond this range were spaced

Figure 6. VR-087 Map.

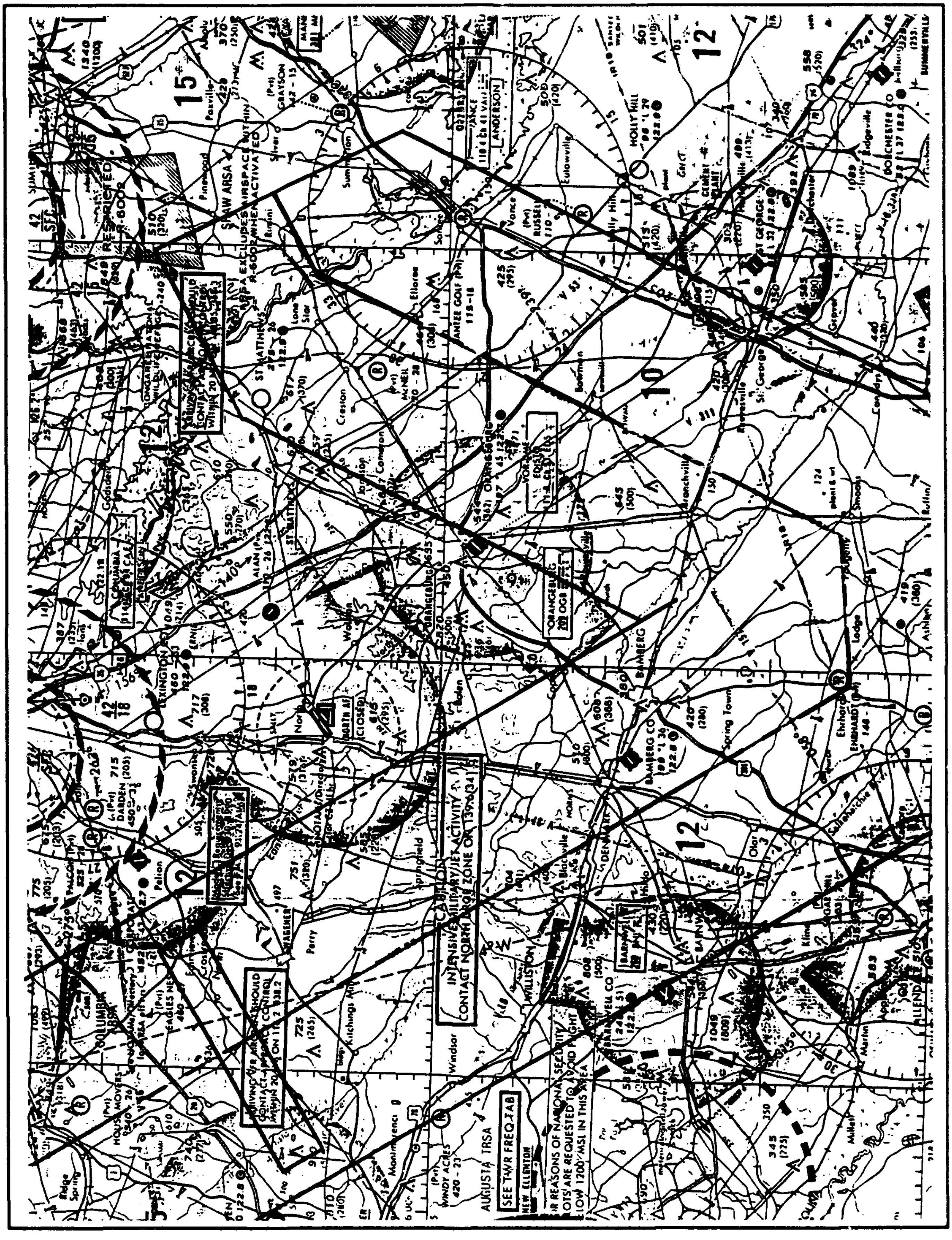

Figure 7. VR-088 Map.

about 0.6 mile. This spread left about 2.5 miles at either edge of the route without monitor coverage, but heavy use was not expected at the edges.

Arrangements were made with the 363rd Fighter Wing at Shaw AFB to obtain schedule information for the route.

3.1.5 VR-1074, North Carolina

This route is located north of Wilmington, NC. Operations along this route consisted of night attack training for F-15s from Seymour Johnson AFB and navigation training for various naval aircraft. Figure 8 shows the portion of VR-1074 between points B and C where operations travel north. This segment of the route is 10 nautical miles across and flight is cleared down to 100 feet AGL. A suitable measurement site was located along a rural highway as shown in Figure 8. The terrain under this segment of the route is primarily coastal wetlands with some rural population.

The measurement array was located along NC Route 53. Twenty-five monitors were located along this road. Near the center of the MTR the monitors were spaced about 0.3 mile apart and the spacing was about 0.4 mile at the edges. Once again, the monitors were chained to telephone poles and trees along the road.

Arrangements were made with 4th TFW at Seymour Johnson AFB to obtain schedule information for the route.

3.2 Instrumentation and Field Procedures

3.2.1 Automatic Noise Monitors

Thirty-five automatic noise monitors were available for these measurements. These consisted of Larson-Davis Model 700 dosimeters, as had been used in previous MTR measurements.[2,4] Fifteen of the dosimeters were fitted with GenRad 1571-9065 1-inch piezoelectric microphones with PCB Piezotronics 402A line amplifiers. The remaining 20 dosimeters were fitted with 3/8-inch Larson-Davis electret microphones. Microphones, along with their windscreens, were placed on 12-inch-square linoleum sheets which were placed

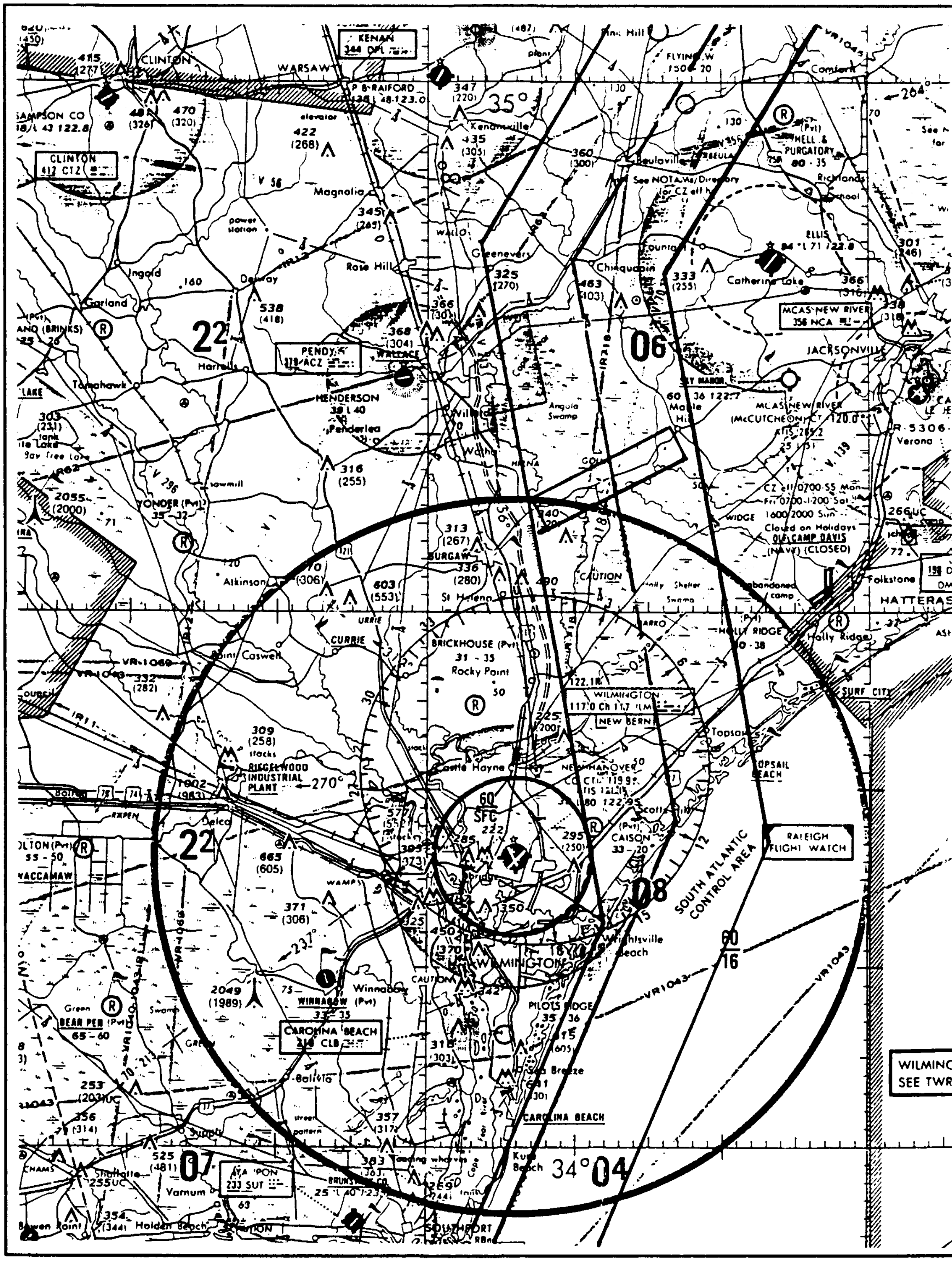

Figure 8. VR-1074 Map.

on the ground. Each LD-700, together with a battery, was placed in an environmentally sealed container. Figure 9 shows a typical monitor site installation. Figure 10 shows the LD-700 and its battery inside the container. Field calibration of the monitors was accomplished using a B&K Type 4230 calibrator.

The LD-700 is a microprocessor-based digital integrating sound level meter. It can be programmed to record interval, exceedance, and history data. Interval data consists of L_{eq} and percentile exceedance levels. Exceedance data consists of records of levels that exceed a preset threshold. History data consists of time histories of noise. The unit can be programmed to record A- or C-weighted levels, slow or fast detector response, and to integrate with 3, 4, or 5 dB/doubling of time tradeoffs, corresponding to L_{eq}, DoD noise dose, and OSHA noise dose. The primary information collected for this project was the exceedance data. The threshold was generally set to 65 dB. It was set higher at sites with significant extraneous noise, so as to avoid recording excessive spurious data. The highest threshold used was 70 dB.

The LD-700s have a bidirectional computer interface. This port can be used to program the unit and to read data from it. A Toshiba T1200XE laptop computer was used for this purpose. The T1200XE is 80286 based, battery powered, has a 3.5-inch floppy disk drive, and operates under the MS-DOS operating system. Software developed for previous MTR measurements[4] was used to initialize and program the LD-700s, and to read data and store them for subsequent analysis. The initialization routine included setting the LD-700's internal clock, so that all monitors were time synchronized.

A maximum of 30 monitors was installed on a given MTR. The remaining five monitors were used as spares when installed units failed. The monitors were placed along rural roads and chained to convenient anchors for security (power line towers, telephone poles, or trees).

The monitors were placed at optimum intervals across the MTRs such that as many as possible would record an overflight. Therefore, if a particular monitor was not operating when an overflight occurred, several other monitors would capture the event. This aided in the identification of overflights from the monitor data. Other considerations in the monitor separation intervals were the width of the route to be covered and the availability of convenient anchor sites.

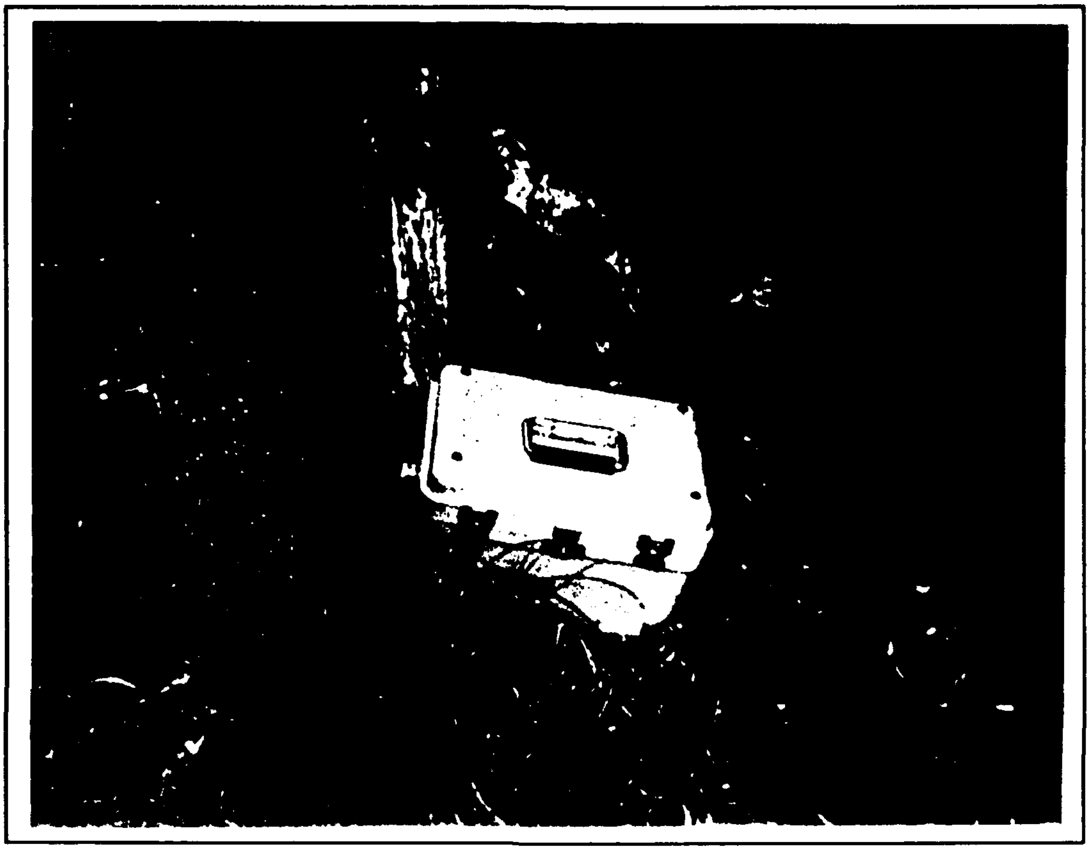

Figure 9. Typical Monitor Installation.

Figure 10. LD-700 and Battery Inside Environmental Case.

3.2.2 Field Service Procedures

Following initial installation, the monitors were checked once per day. A check-up visit would proceed as follows:

1. The unit was approached and a visual inspection made of the site. The time of day was noted on the daily log.

2. The environmental case was opened. The basic operation of the unit was checked by observing the unit response to noise events.

3. The memory status of the unit was checked and noted in the daily log. If a substantial amount of the memory was full, the download/reset procedure was performed. If only a small portion of the memory was occupied with data, the site visit was continued with step 7, below.

4. Monitors with a substantially full memory were stopped at this point. The calibrator was placed on the microphone and the unit restarted. This ensured that the last exceedance in the memory was the calibration signal. The measured calibration level was noted in the daily log and the unit turned off.

5. The unit was removed from the environmental case and interfaced with the laptop computer. All exceedance histories were downloaded from the unit and the operation parameters (including the internal clock) were reset.

6. The unit was then returned to its environmental case and the calibration signal was again recorded. This ensured that the first exceedance record was the calibration tone. If necessary at this point, the unit calibration was adjusted. The unit was restarted and the time was recorded in the daily log.

7. Battery voltages were checked and recorded in the daily log. If necessary, the battery was replaced with a fresh one. Also, any faulty components were replaced or repaired.

8. Finally, the environmental case was closed and locked.

Depending on the noise environment in which a monitor was located, data were download. at most every day and at least every third day. Occasionally the memory in a unit would be full due to a lost windscreen, livestock or rodent interference, or other unpredictable events. In this case, the unit would be inoperable until the next site visit.

If a particular unit was discovered to be dysfunctional, the unit was pulled from the field and replaced with a spare. The rechargeable batteries usually lasted 7 to 10 days before replacement was necessary.

4.0 DATA ANALYSIS AND RESULTS

4.1 Data Analysis Procedures

Following completion of the field programs, data from the monitors were collated and correlated with the route schedule and field log. This information was compiled into an inventory of events from which statistical and other conclusions could be drawn. Reduction of the data consisted of the following steps:

1. A composite list of scheduled and observed flights was compiled.

2. All data files from the monitors were printed out. Figure 11 shows part of a typical exceedance report from a monitor located under the centerline of VR-1220. Aircraft flyover events are indicated.

3. Beginning with known (observed) events, the general pattern of exceedance records was established. This included identifying typical maximum levels, durations, and the correlation between different monitors.

4. Next, all monitor data/files were examined for exceedance events which corresponded to aircraft overflights. These events were correlated with the schedule information.

5. Finally, a listing of all recorded events was compiled. This list included the exceedance information from each monitor site which recorded the event.

A single-ship overflight generated exceedance records as follows: the monitor closest to being directly under the aircraft would show a maximum level in excess of 90 dBA and a duration of 15 to 25 seconds, while adjacent and more distant monitors would show corresponding lower levels of shorter duration. A two-ship, line-abreast formation would exhibit two peaks 0.5 to 1 mile apart. Figure 12 shows one such event. An ideal four-ship box formation would exhibit four distinct maximum levels, corresponding to two line-abreast records about 30 seconds apart.

Data reduction consisted of extracting these patterns from monitor exceedance reports. Most exceedances recorded did not correspond to aircraft, but to road traffic noise, farm equipment, rain storms, livestock, and other animals. Aircraft exceedances were easily discerned from the other exceedance

	Cnt	LVL	SEL	Lmax	Lpk	Date	Time	Dur		Pk	Ov
cal	1	93.5	105.0	93.5	100.0	4 FEB	12:59:49	0:14	m:s	0	0
	2	72.0	79.0	74.5	91.5	5 FEB	7:15:03	0:05	m:s	0	0
	3	71.0	76.0	73.0	86.0	5 FEB	7:28:31	0:03	m:s	0	0
	4	71.5	76.5	74.0	87.0	5 FEB	7:44:26	0:03	m:s	0	0
	5	69.5	74.0	71.5	88.0	5 FEB	7:48:21	0:02	m:s	0	0
	6	75.0	82.5	79.0	95.5	5 FEB	8:01:19	0:05	m:s	0	0
	7	69.0	71.0	70.5	83.0	5 FEB	8:07:32	0:01	m:s	0	0
	8	70.0	75.0	72.0	85.0	5 FEB	8:07:43	0:03	m:s	0	0
	9	74.0	81.0	77.5	91.0	5 FEB	8:21:11	0:05	m:s	0	0
	10	70.5	75.5	72.0	85.0	5 FEB	8:22:53	0:03	m:s	0	0
	11	70.5	77.0	72.5	86.0	5 FEB	8:36:08	0:04	m:s	0	0
	12	71.0	84.5	74.5	88.5	5 FEB	8:46:40	0:21	m:s	0	0
	13	70.0	73.5	72.0	86.0	5 FEB	8:51:34	0:02	m:s	0	0
	14	69.0	71.0	70.5	82.5	5 FEB	9:14:21	0:01	m:s	0	0
*	15	81.0	91.5	86.0	101.5	5 FEB	10:05:41	0:11	m:s	0	0
	16	72.0	77.5	75.0	92.5	5 FEB	10:45:29	0:03	m:s	0	0
*	17	80.5	94.5	87.5	101.5	5 FEB	11:18:54	0:23	m:s	0	0
	18	73.5	79.5	77.0	94.5	5 FEB	11:31:12	0:04	m:s	0	0
	19	71.0	76.0	73.0	86.0	5 FEB	11:47:46	0:03	m:s	0	0
*	20	96.0	107.5	104.0	122.5	5 FEB	11:52:59	0:14	m:s	1	0
	21	70.5	75.0	72.5	87.5	5 FEB	11:56:11	0:02	m:s	0	0
	22	72.0	77.5	74.0	86.5	5 FEB	11:58:45	0:03	m:s	0	0
	23	70.5	75.5	72.5	87.0	5 FEB	12:00:12	0:03	m:s	0	0
	24	70.0	75.0	71.5	83.5	5 FEB	12:02:42	0:03	m:s	0	0
	25	71.5	75.5	75.5	110.5	5 FEB	12:30:00	0:02	m:s	0	0
	26	69.5	72.0	72.5	97.5	5 FEB	12:30:07	0:01	m:s	0	0
	27	71.0	75.0	73.5	99.5	5 FEB	12:30:09	0:02	m:s	0	0
	28	70.0	75.5	72.0	85.5	5 FEB	12:31:49	0:03	m:s	0	0
*	29	85.0	95.5	90.0	106.5	5 FEB	13:11:26	0:10	m:s	0	0
	30	70.0	74.0	71.5	85.5	5 FEB	13:22:40	0:02	m:s	0	0

* Identified Aircraft

Figure 11. Excerpt From Typical Exceedance Report From VR-88 Site 17. Calibration and Flyover Events Noted.

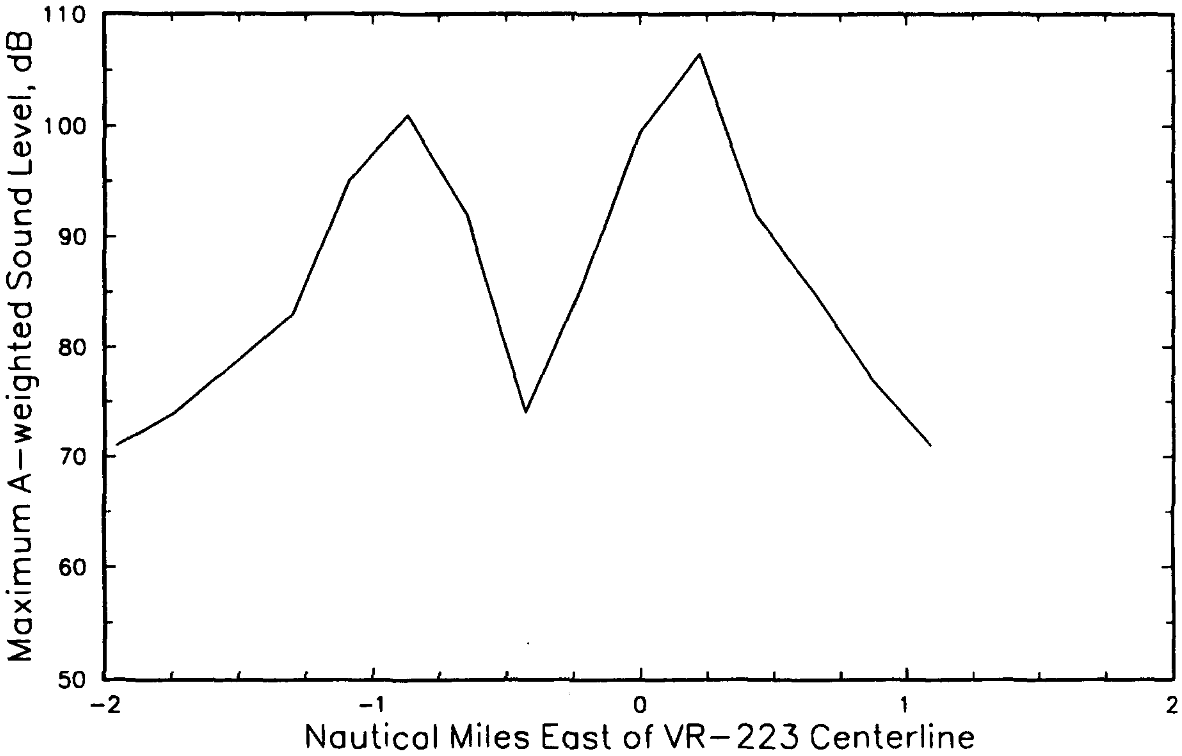

Figure 12. Sound Level Distribution for a Two-Ship Formation.

sources. An aircraft overflight would be recorded by at least three monitors simultaneously with the characteristics discussed previously. Other noise sources rarely triggered more than one monitor at a time.

Once all aircraft exceedances were gathered and correlated, the location of each aircraft was assumed to be coincident with the monitor showing the maximum noise level. The remaining analysis consisted of statistical descriptions of overflight locations and levels at each site.

4.2 Schedule Data and Measurement Correlation

Tables 1 through 5 contain the operations schedules for VR-1220, VR-223, VR-87, VR-88, and VR-1074, respectively. Each table lists the date, entry time, type of aircraft, and number of aircraft for each mission. The final column lists the number of sorties in each mission that were detected by the monitor array. A mission, in the following discussions, refers to a group of aircraft operating in unison (and usually scheduled together). A sortie refers to an individual aircraft which may be part of a mission. Tables 1 through 5 do not include detected aircraft which were not scheduled for these routes.

4.2.1 VR-1220, Arizona

The schedule information in Table 1 is for VR-1220. All of the scheduled missions operating on VR-1220 from 4 March to 28 March 1991 are listed. A total of 172 sorties were scheduled in 77 missions, 22 of which were F-15s and 55 were F-16s. Of the 172 sorties that were scheduled during this period, 53 went undetected by the monitor array. Of the 53 undetected sorties, 47 sorties (in 19 missions) were from missions where none of the sorties in the mission were detected. It is possible that a single aircraft in a mission could pass through a region of sparse monitor spacing and/or non-operating monitors and hence go undetected. It is unlikely, however, that all aircraft in a mission could pass the array undetected since a typical mission would span at least 0.5 mile (and usually more). For this reason it is likely that most, if not all, of the 19 missions that went completely undetected did not pass over the array. These missions may have been grounded due to weather or left the route before reaching the monitor array for other reasons. In fact, heavy rains, thunderstorms, and hail were

Table 1

VR-1220 Schedule

Date	Time	Aircraft Type	No. of Aircraft	Number Identified
4 March	1510	F-16	3	2
	1900	F-16	2	2
	1900	F-16	2	2
	1910	F-16	2	2
	1930	F-16	2	2
	1935	F-15	2	2
5 March	1210	F-15	2	0
	1250	F-15	4	4
	1520	F-16	2	2
	1835	F-15	3	0
	1930	F-16	2	2
	1940	F-16	2	2
6 March	1510	F-16	3	3
	1540	F-16	3	0
	1825	F-15	3	3
	1830	F-15	3	3
	1930	F-16	2	0
	2000	F-16	2	0
7 March	1240	F-15	2	0
	1240	F-15	2	2
	1830	F-15	3	1
	1850	F-16	2	2
	1930	F-16	2	2
	1930	F-16	2	0
	2000	F-16	2	1
8 March	1105	F-16	2	2
11 March	0935	F-15	2	2
	1015	F-15	2	2
	1600	F-16	1	1
12 March	0925	F-15	2	2
	1905	F-15	2	2
	1945	F-15	2	2
	2025	F-15	2	2
13 March	1545	F-16	2	2
14 March	1130	F-16	2	1
	1520	F-16	2	2
18 March	1020	F-16	1	1
	1050	F-16	3	3
	1500	F-16	2	2
	1905	F-15	3	3
	1935	F-15	2	2
	2005	F-15	2	2

Table 1 (Concluded)

Date	Time	Aircraft Type	No. of Aircraft	Number Identified
19 March*	1020	F-16	3	0
	1530	F-16	3	3
	1850	F-16	2	2
	1850	F-16	2	2
	1905	F-15	3	3
	1935	F-15	2	2
	2005	F-15	2	2
20 March*	1230	F-16	2	2
	1600	F-16	2	0
21 March	1030	F-16	2	2
	1040	F-16	2	2
	1100	F-16	2	2
25 March	1140	F-16	2	2
	1150	F-16	2	2
	1210	F-16	2	2
	1600	F-16	2	2
	1630	F-16	2	2
	1630	F-16	2	2
26 March*	1130	F-16	2	0
	1200	F-16	4	0
	1600	F-16	2	0
	1610	F-16	2	0
	1630	F-16	2	0
27 March*	1430	F-16	3	0
	1730	F-16	2	0
	1850	F-16	3	0
28 March	1130	F-16	4	0
	1140	F-16	2	2
	1605	F-16	2	2
	1625	F-16	2	2
29 March	1040	F-16	2	2
	1040	F-16	2	1
	1110	F-16	2	2
	1110	F-16	2	2
	1140	F-16	2	0
TOTALS		77 Missions	172 Sorties	119 Identified

* Inclement Weather.

Table 2

VR-223 Schedule

Date	Entry Time	Aircraft Type	No. of Aircraft	Number Identified
3 April	1340	F-16	4	4
	1435	F-15	2	2
4 April	0920	F-16	4	4
5 April	0920	F-16	2	2
9 April	0735	F-15	2	2
10 April	0905	F-16	4	4
	1325	F-16	4	4
	1338	F-16	4	0
11 April	0910	F-16	4	4
12 April	0910	F-16	2	2
	1015	F-15	2	2
	1500	F-15	2	2
15 April	1405	F-16	4	4
16 April	0915	F-15	1	1
	1450	F-16	4	4
	1515	F-15	2	2
17 April	0945	AV-8	2	1
18 April	1620	AV-8	2	2
	1935	F-15	2	2
19 April	0920	AV-8	2	2
	1020	F-16	4	4
22 April	1325	F-15	2	2
	1538	F-16	2	2
23 April	0910	F-16	4	4
	1350	F-16	4	4
	1400	F-15	2	0
24 April	0920	F-16	4	4
25 April	0805	F-16	2	1
	0920	F-16	4	3
	1330	F-15	2	2
TOTALS		30 Missions	85 Sorties	76 Identified

Table 3

VR-87 Schedule

Date	Entry Time	Aircraft Type	No. of Aircraft	Number Identified
8 October	1335	F-16	2	2
	1555	F-16	2	2
9 October	1530	F-16	2	2
10 October	1435	F-16	2	0
	1535	F-16	4	4
11 October	1215	F-16	4	4
	1455	F-16	2	2
15 October	1235	F-16	2	2
	1335	F-16	2	0
16 October*	925	F-16	2	2
	935	F-16	4	0
	1335	F-16	4	4
17 October	915	F-16	2	2
21 October	1415	F-16	3	3
22 October	1725	F-16	4	4
29 October	1010	F-16	2	2
	1025	F-16	2	2
	1055	F-16	4	4
	1355	F-16	4	4
30 October	1050	F-16	2	2
	1535	F-16	4	4
31 October	1015	F-16	2	2
	1050	F-16	4	0
	1355	F-16	4	0
	1435	F-16	4	0
4 Nov*	850	F-16	2	2
	1330	F-16	4	0
5 Nov	800	F-16	4	4
	853	F-16	4	4
	915	F-16	4	4
	1034	F-16	4	4
	1133	F-16	4	4
	1425	F-16	4	4
6 Nov	1140	F-16	4	4
	1200	F-16	4	4
	1545	F-16	2	0
7 Nov	1010	F-16	4	0
	1420	F-16	4	0
	1520	F-16	4	0
8 Nov	1135	F-16	4	4
TOTALS		40 Missions	129 Sorties	95 Identified

* Rain or Inclement Weather.

Table 4

VR-088 Schedule

Date	Entry Time	Aircraft Type	No. of Aircraft	Number Identified
18 Nov	1415 1445	F-16 F-16	2 4	2 4
19 Nov	1455	F-16	2	2
20 Nov	1435	F-16	2	2
24 Nov	0828	F-16	2	0
25 Nov	1205 1315 1350	F-16 F-16 F-16	2 4 2	2 4 2
26 Nov	1400	F-16	2	2
27 Nov	1320	F-16	4	4
3 Dec	1015	F-16	4	4
5 Dec	1030	F-16	2	2
6 Dec	0950 1035	F-16 F-16	2 2	2 2
10 Dec	0945 1005 1040	F-16 F-16 F-16	4 4 4	4 4 4
11 Dec	0923 1335	F-16 F-16	4 4	0 4
13 Dec	1000	F-16	2	2
TOTALS		20 Missions	58 Sorties	52 Identified

Table 5

VR-1074 Schedule

Date	Time	Aircraft Type	No. of Aircraft	Number Identified
3 February	1025	F-15	4	4
	0940	AV-8	2	0
	1535	F-15	2	2
	1645	F-15	2	2
4 February	0820	AV-8	2	2
	0900	AV-8	2	2
	0925	AV-8	2	2
	1015	A-6	2	2
	1030	AV-8	2	0
	1415	A-6	1	0
	1420	T-38	2	2
	1515	A-6	2	2
	1540	AV-8	2	0
	1610	F-15	4	4
	1645	A-6	1	1
5 February	0945	AV-8	2	2
	1100	A-6	2	2
	1140	F-15	2	2
	1250	AV-8	2	2
	1435	F-15	2	2
	1457	F-15	2	2
	1502	AV-8	2	2
	1515	AV-8	2	2
	1550	AV-8	2	2
	1605	F-15	4	4
6 February	0945	A-6	1	1
	1035	F-15	2	2
7 February	0835	AV-8	2	0
	1250	AV-8	1	1
8 February	1500	A-6	2	0
9 February		No Schedule		
10 February	1755	F-15	2	2
	1805	F-15	2	2
	1820	F-15	2	0
11 February*	0815	F-15	4	4
	0925	AV-8	2	0
	1135	AV-8	2	2
	1251	F-15	2	2
	1300	F-15	2	2
	1725	F-15	2	2
	1735	F-15	2	2
	1800	F-15	3	3
	2037	F-15	3	3
	2100	F-15	3	3

Table 5 (Continued)

Date	Time	Aircraft Type	No. of Aircraft	Number Identified
12 February	0830	AV-8	2	2
	0900	F-15	4	4
	1130	F-15	4	4
	1200	T-38	2	2
	1300	F-15	2	2
	1505	F-15	1	1
	1515	AV-8	2	0
	2015	F-15	2	2
	2035	F-15	3	3
	2215	F-15	2	2
13 February	0820	AV-8	2	0
	0903	F-15	4	0
	1010	A-6	2	0
	1020	A-6	2	0
	1138	F-15	4	0
14 February*	0930	AV-8	3	0
	1100	F-15	1	1
	1213	F-15	2	2
	1230	F-15	2	2
15 February	1540	AV-8	1	1
16 February		No Schedule		
17 February		No Schedule		
18 February	1905	F-15	2	0
19 February	1130	A-6	2	2
	1245	F-15	2	2
	1613	F-15	4	4
	1920	F-15	2	2
20 February	0800	F-15	4	4
	1050	F-15	4	4
	1100	AV-8	2	2
	1110	AV-8	2	2
	1133	F-15	4	4
	1615	F-15	4	4
	2138	AV-8	2	2
21 February	0830	A-6	1	1
	1040	F-15	2	2
	1500	AV-8	2	2

Table 5 (Concluded)

Date	Time	Aircraft Type	No. of Aircraft	Number Identified
22 February	1230	A-6	1	1
	1715	F-18	1	1
23 February		No Schedule		
24 February	1330	AV-8	2	2
	1755	F-15	2	2
25 February		No Schedule		
26 February	1058	F-15	4	0
	1130	F-15	1	0
	1350	F-15	2	0
	1739	F-15	2	0
	1545	AV-8	2	2
27 February	0800	F-15	4	4
	0915	F-15	1	0
	1105	F-15	4	4
	1334	F-15	2	2
	1435	F-15	2	2
	1449	F-15	2	2
	1759	F-15	2	2
28 February	0945	F-15	2	2
	1035	AV-8	1	1
	1245	F-15	2	2
	1210	A-6	1	1
	1220	F-15	1	1
	1419	AV-8	3	0
TOTALS		100 Missions	224 Sorties	175 Identified

* Inclement Weather.

observed on 26 and 27 March. Notice that none of the eight missions scheduled for these two days was detected by the monitors. Rain was also noted on the afternoon of 20 March. A mission of two F-16s was scheduled but not detected on this day.

If the 9 missions which were not detected by the monitors and occurred on days when inclement weather was noted are removed from the schedule, then a total of 68 missions (150 sorties) were scheduled for the period. Of these, 31 sorties (about 20 percent) went undetected by the monitors. If all 19 missions of which no sorties were detected are removed from the schedule, a total of 58 missions (127 sorties) were scheduled. Of these, only 6 sorties (about 5 percent) went undetected.

In addition to the scheduled missions, 34 missions (consisting of 43 sorties) were recorded by the noise monitors which did not appear on the schedule. Of these 34 missions, 28 consisted of a single aircraft. Many of these unscheduled missions were apparently A-10s which were observed in the area.* The total number used in the statistical analysis was 162 sorties contained in 83 missions: the total of all detected scheduled missions, plus the unscheduled A-10s.

4.2.2 VR-223, Arizona

Table 2 lists the schedule data for VR-223 for the measurement period of 3 April through 25 April 1991. A total of 30 missions were flown during this period. Of these 30 missions, 17 were F-16s, 10 were F-15s and 3 were AV-8s. These 30 missions constituted 85 sorties of which 76 sorties (about 90 percent) were recorded by the monitors. Of the 9 sorties that went undetected, 6 sorties were from missions where none of the aircraft were detected. As discussed previously, it is unlikely that all aircraft in a mission could pass the monitors undetected. It is more likely that these missions either did not fly or left the route before reaching the measurement array. Another possibility is that the undetected sorties flew over the eastern portion of the route which contained no monitors. This part of the route was generally avoided by the aircraft due to the mountainous terrain, and would have involved substantially higher altitude.

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* A-10s fly at lower speeds, and therefore do not necessarily have to schedule route usage.

In addition to the scheduled flights, 26 missions (consisting of 39 sorties) were measured which did not appear on the schedule. Again, these were apparently A-10s. Of the 26 unscheduled missions, 17 consisted of a single sortie. The total number used for the statistical analysis was 115 sorties contained in 56 missions, the total of detected scheduled missions plus detected unscheduled missions.

4.2.3 VR-087, South Carolina

Table 3 lists the schedule data for VR-087 during the measurement period of 8 October through 8 November 1991. A total of 40 missions consisting of 129 sorties were scheduled during this period. All of the scheduled missions were for F-16 aircraft. Of the 129 scheduled sorties, 95 (or about 75 percent) were detected by the noise monitors leaving 34 undetected sorties. All of the undetected sorties were contained in missions which had no sorties detected. It is reasonable to assume that most, if not all, of the undetected missions did not cross the measurement array.

No unscheduled missions were measured by the monitors on this route. The total sortie count used in the statistical analysis was 95 contained in 40 missions.

4.2.4 VR-088, South Carolina

Table 4 contains the schedule data for VR-088 through the measurement period of 18 November to 13 December 1991. A total of 20 missions containing 58 sorties of F-16s were scheduled for the period. Of these 58 scheduled sorties, 52 (about 90 percent) were measured by the monitors. All of the undetected sorties were from missions with no detected aircraft. These missions were probably canceled or exited the route before reaching the measurement array.

No unscheduled missions were recorded on this route. The total sortie count used in the statistical analysis was 52 contained in 18 missions.

4.2.5 VR-1074, North Carolina

Table 5 lists the schedule data for VR-1074 through the measurement period of 3 February to 28 February 1992. A total of 100 missions containing 224 sorties were scheduled over the period. Most of these aircraft were F-15s and AV-8s. Of the 224 sorties, 175 (about 78 percent) were detected by the monitors. All of the undetected sorties were scheduled within missions where no aircraft were detected. These missions probably left the route before reaching the monitors, flew around the monitors, or were canceled due to weather. Morning fog was noted in the area on the 11 and 14 February and heavy rain was reported in the area most of the day on 26 February. These days of inclement weather account for 11 undetected, scheduled sorties. Removing these from the schedule makes the detection rate 85 percent.

In addition, 15 missions consisting of 25 sorties were detected which did not appear on the schedule. The total number used for the statistical analysis was 200 sorties contained in 93 missions.

4.3 MTR Measurement Results

The discussion of the measurement results revolves around several figures which require some introduction. There are four figures for each of the five routes. Figures 13 through 16 correspond to VR-1220, and consist of the following:

- Figure 13 shows the distribution of sorties recorded by the measurement arrays. The positions of individual sorties were assumed to be over the monitor site which recorded the maximum level. In each figure a plot of the raw data and smoothed data are shown. The smoothed data was calculated from the weighted average of the site and the two sites adjacent to it. The site was weighted 50 percent and the two adjacent sites were weighted 25 percent. Since the total number of events at any particular site were statistically low, the smoothed distribution is probably a better representation of the data.

- Figure 14 shows the cumulative probability distribution of position. In the case of a perfectly Gaussian distribution this plot would appear as a

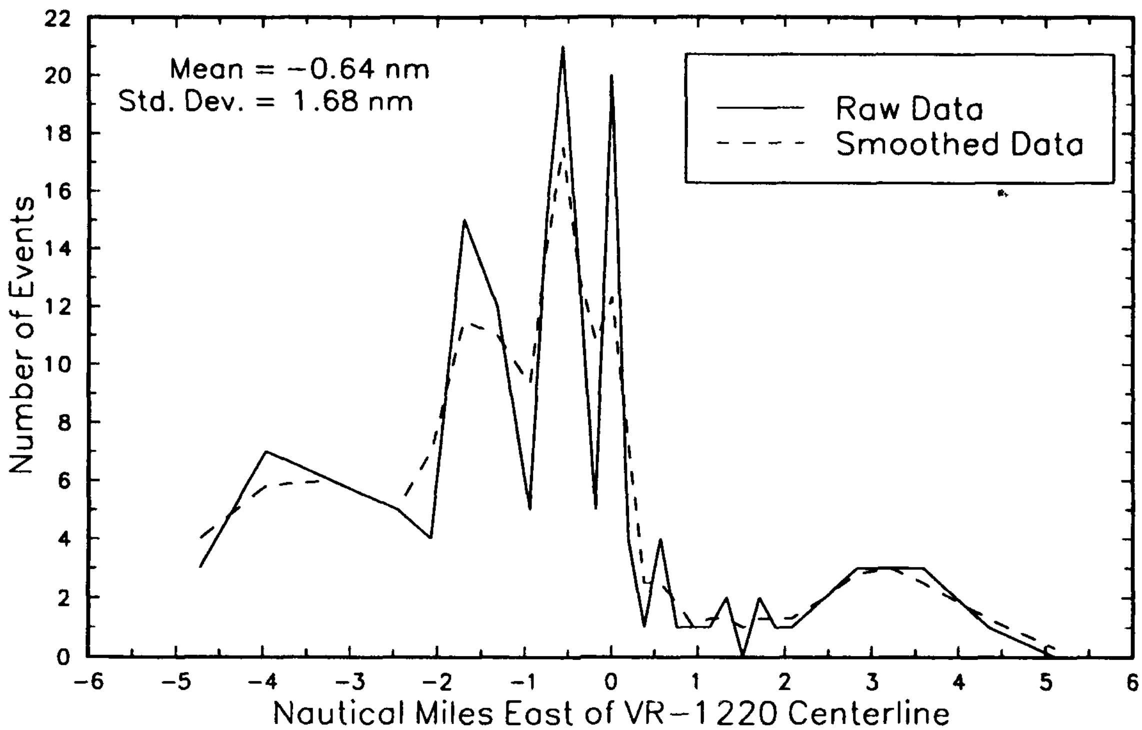


Figure 13. VR-1220 Event Distribution.

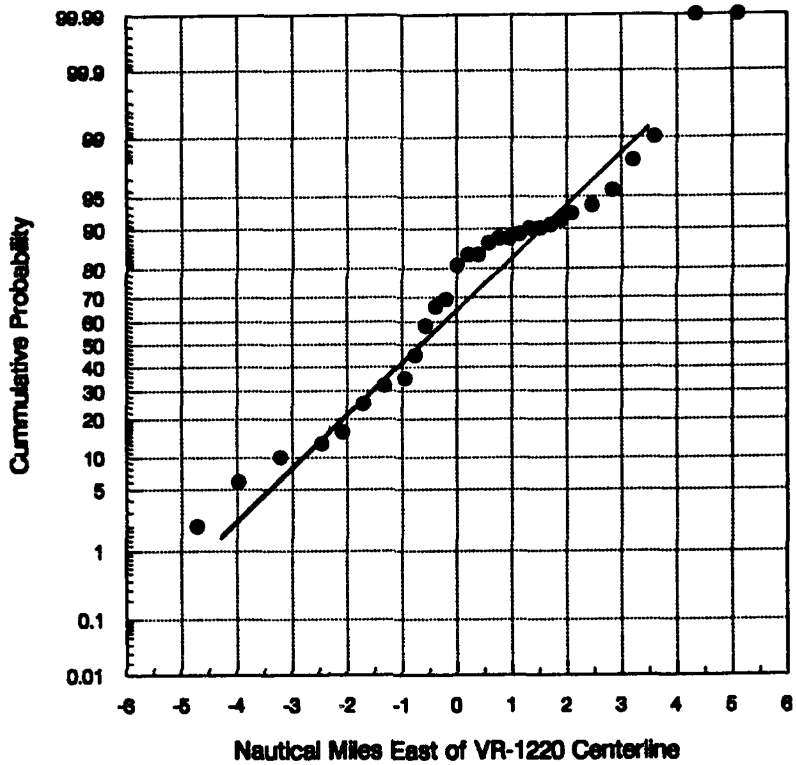


Figure 14. VR-1220 Event Cumulative Probability Distribution.

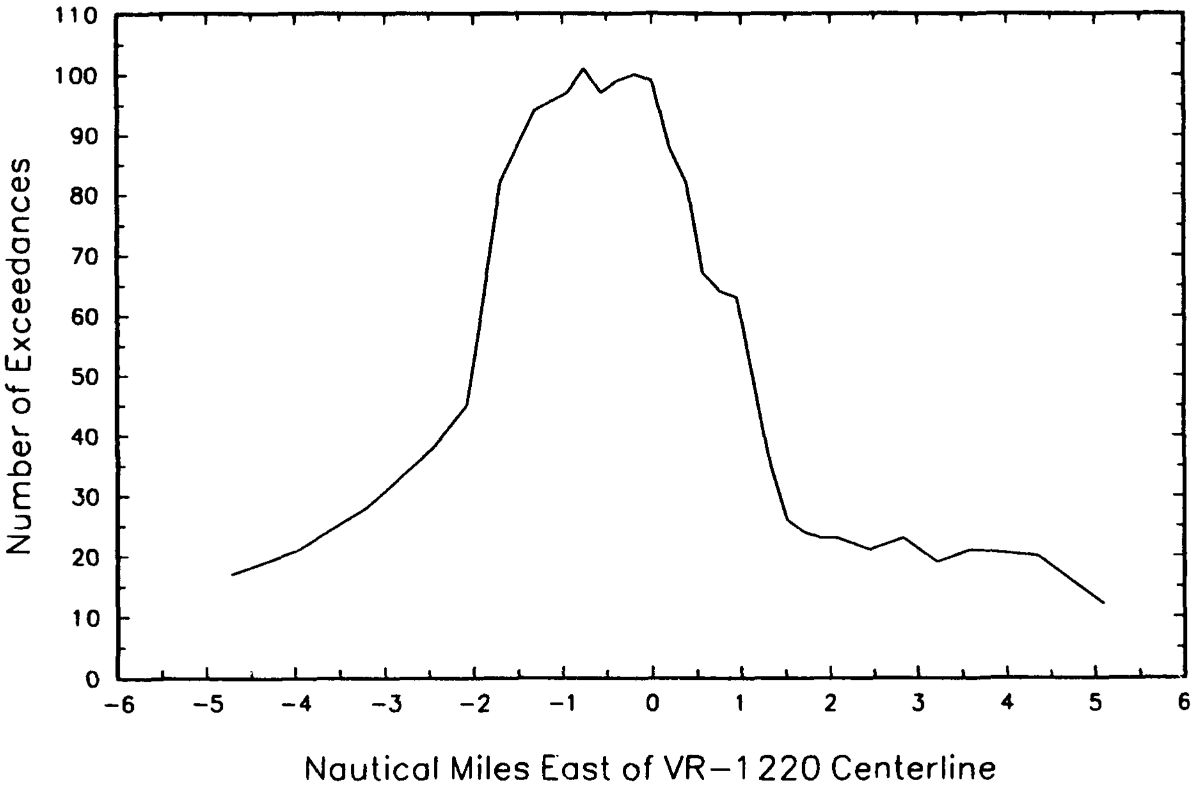
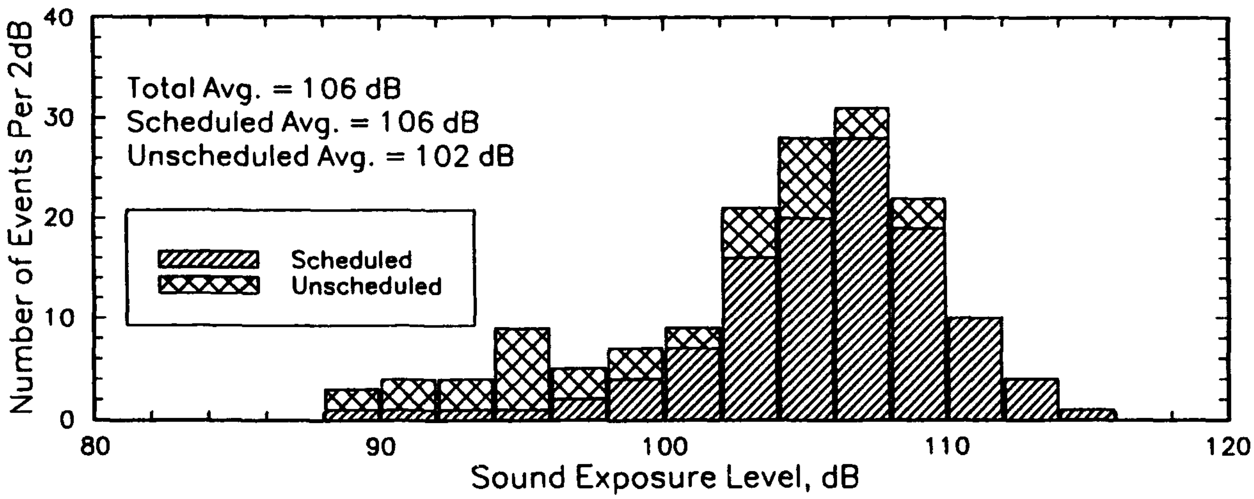
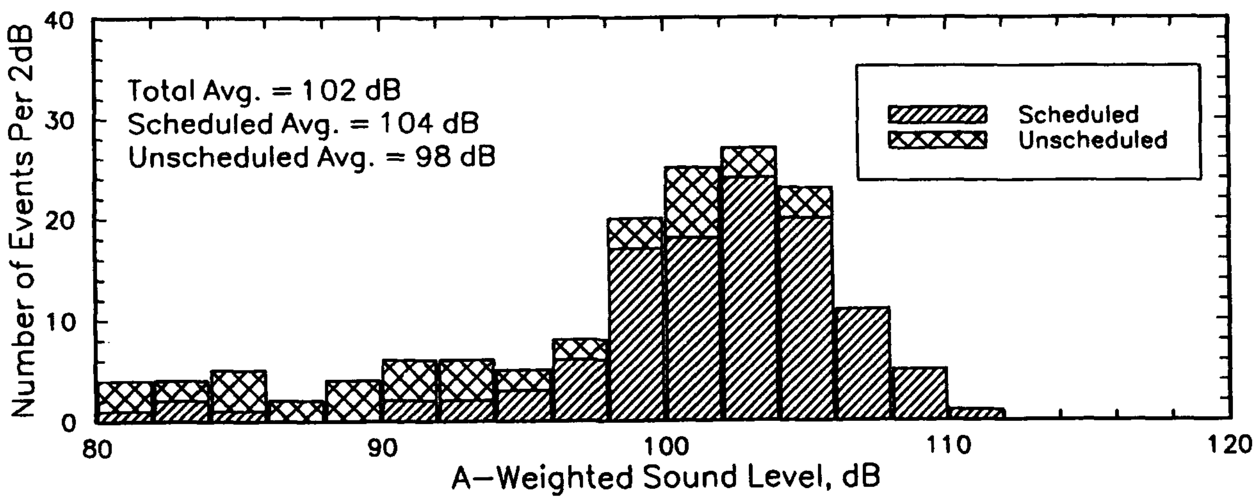


Figure 15. VR-1220 Total Events at Each Site.



(a) Distribution of Highest SEL for Each Event.



(b) Distribution of Highest Maximum Level for Each Event.

Figure 16. Distribution of Event Sound Levels, VR-1220.

straight line. Each of these plots contains the individual site data points along with an ideal Gaussian straight line for comparison.

- Figure 15 shows the total number of events recorded at each site. This represents the number of aircraft which exceeded the monitor threshold level of 65 to 70 dB during the four-week measurement period.

- Figure 16 shows the distributions of the measured sound exposure level and maximum level. These are the maximum for each event, and represent noise levels occurring within half the monitor spacing of the flight track. In addition, the measured levels are split between scheduled and unscheduled events.

4.3.1 VR-1220 Measurement Results

The distribution obtained for VR-1220, shown in Figure 13, has a mean of -0.64 nautical mile and a standard deviation of 1.68 nautical miles. The offset of the distribution toward the west may be due to higher terrain east of the route centerline. The aircraft tended to fly to the west, avoiding this higher terrain. The cumulative probability distribution for VR-1220 is shown in Figure 14. If the data distribution were perfectly Gaussian it would appear as a straight line on the probability plot. A line has been drawn on Figure 14 corresponding to a Gaussian distribution having a mean of -0.64 nautical mile and a standard deviation of 1.68 nautical miles. As is evident, the actual data follows the straight line fairly well with some deviation just east of the route centerline.

The total number of events recorded at each site are shown in Figure 15. These include all exceedances (i.e., sound levels above the threshold of 65 to 70 dB) associated with aircraft overflights, not just the maximum.

Figure 16(a) shows the distribution of Sound Exposure Levels per 2 dB increment for each detected sortie. This is a count of the number of events whose event-center SEL fell within each 2 dB bin. For example, for VR-1220, 32 of the measured events had a minimum SEL between 106 dB and 108 dB. The energy-average sound level for this distribution is 105.6 dB. Given the type of aircraft on the route and their proportionate number of operations, the average operating altitude of the aircraft can be estimated. For example, on VR-1220 about two-

altitude of the aircraft can be estimated. For example, on VR-1220 about two-thirds of the operations were F-16s and the remaining one-third were F-15s. It is known that an F-16 flying at 500 feet under typical MTR flight conditions produces an SEL of 102 dB on the ground. Similarly, an F-15 produces an SEL of 105 dB. Therefore, if all of the aircraft on VR-1220 flew at 500 feet they would produce an energy-average SEL of 103 dB. Since the energy-average SEL for the VR-1220 measurements was 105.6 dB, it can be inferred that the aircraft were operating at an average altitude of about 300 feet.

The distribution in Figure 16(a) is also split between scheduled and unscheduled events. The energy average was 106 dB for scheduled events and 102 dB for unscheduled events. The significantly lower levels associated with the unscheduled events are due to A-10s which produce relatively low noise levels.

A similar plot is shown in Figure16(b) for the maximum level associated with each event. The energy average maximum level on VR-1220 was 101.6 dB. As before, the average level of unscheduled events is significantly lower than for scheduled events.

4.3.2 VR-223 Measurement Results

The distribution obtained for VR-223, shown in Figure 17, has a mean of -0.59 nautical mile and a standard deviation of 0.93 nautical miles. The offset of the mean is due to Tabletop Mountain under the eastern part of the route, which the aircraft had to fly around. The cumulative probability distribution for VR-223 is shown in Figure 18. The data obtained follows the straight line of an ideal normal distribution fairly well. The total exceedances measured at each site are shown in Figure 19.

Unlike VR-1220, where all operations were well contained within the route boundaries, operations on VR-223 extended to the western edge. It appears that the three miles available at this choke point is close to the minimum necessary for this type of route. The standard deviation is the smallest measured on any TAC route.

Figure 20(a) shows the distribution of SELs per 2 dB for each measured event. The energy average associated with these measurements is 105.1 dB. This

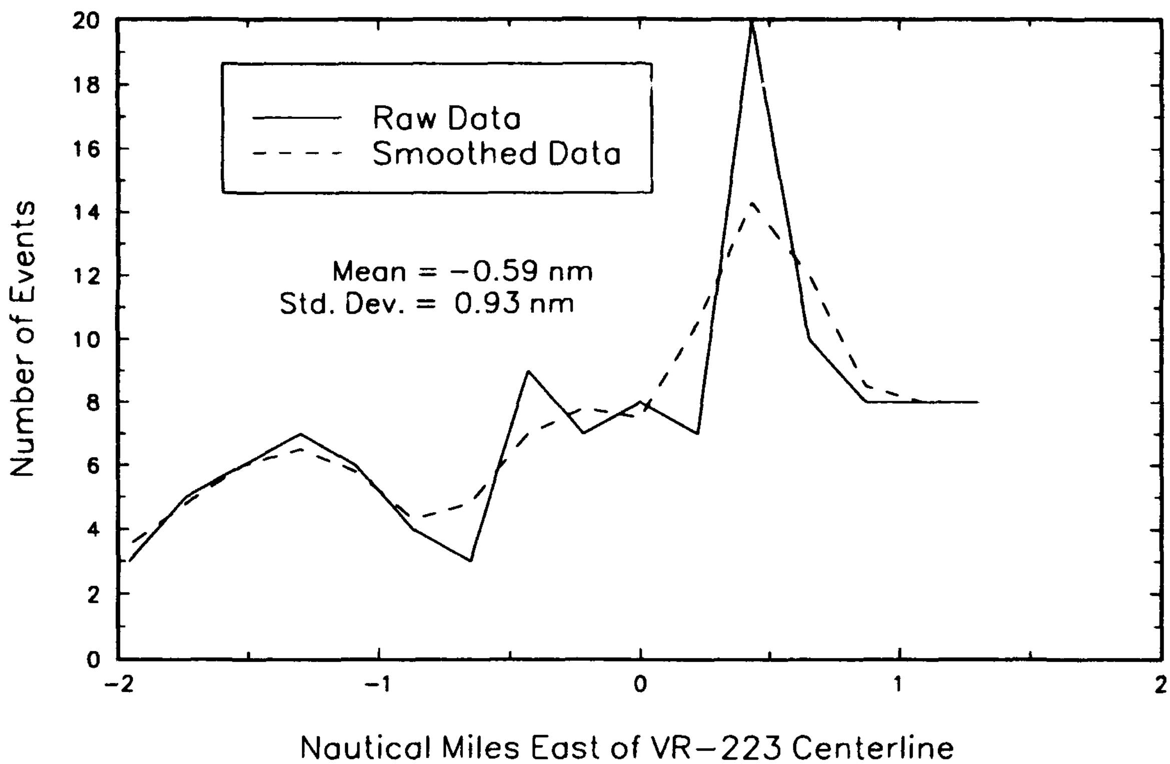


Figure 17. VR-223 Event Distribution.

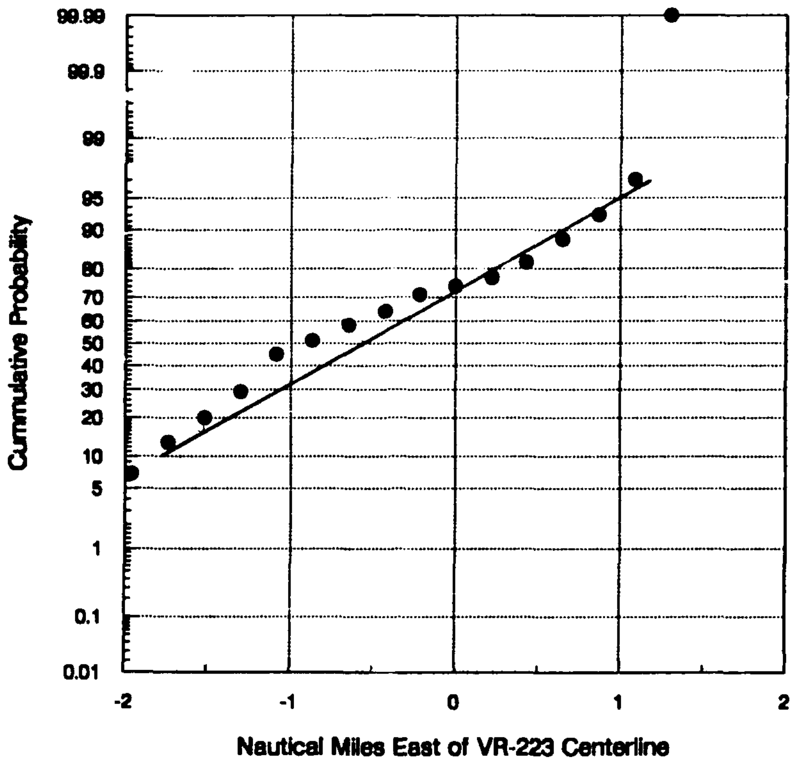


Figure 18. VR-223 Event Cumulative Probability Distribution.

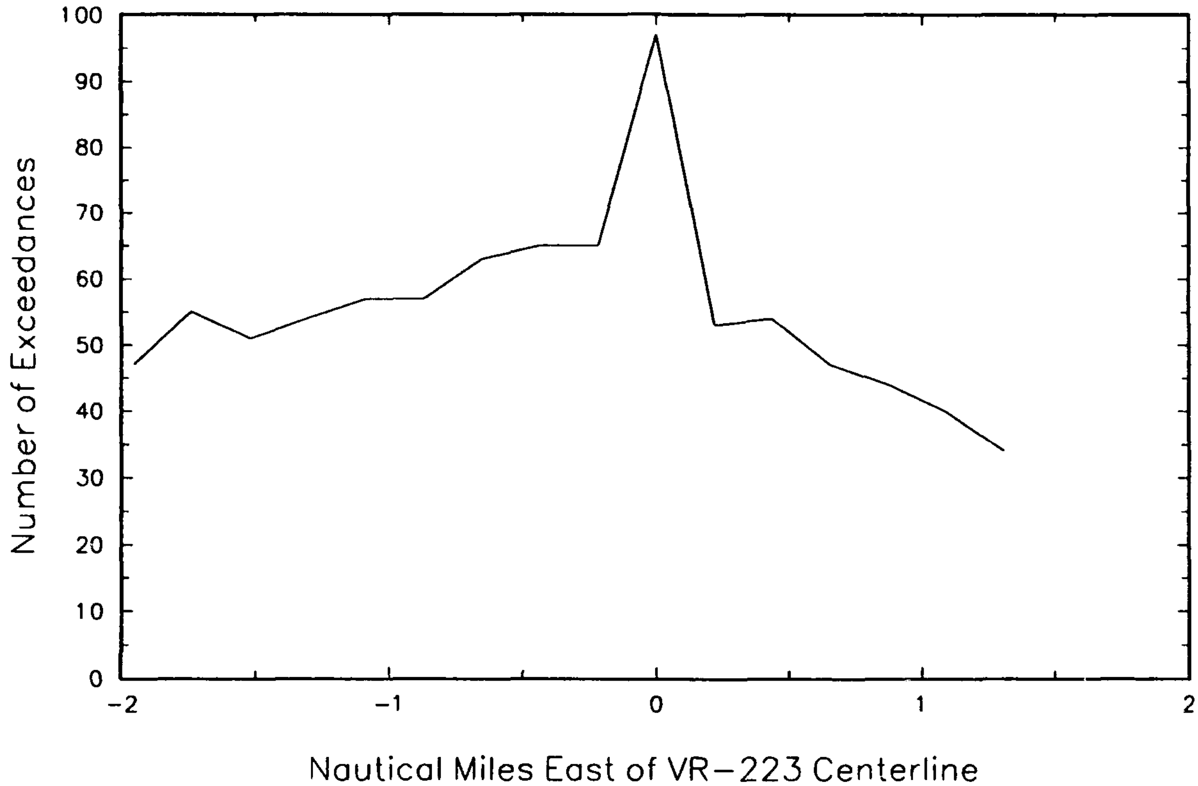
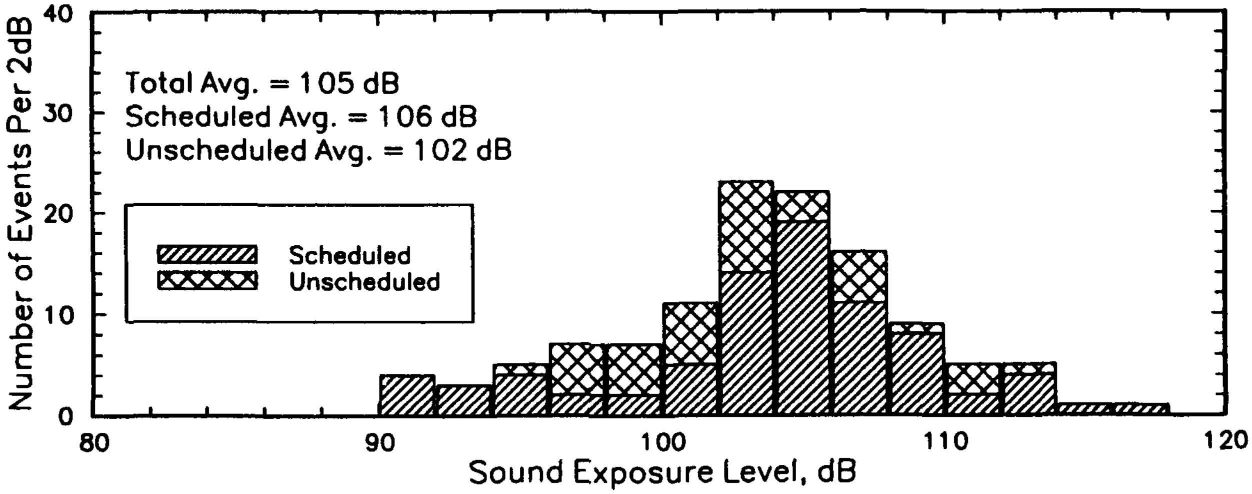
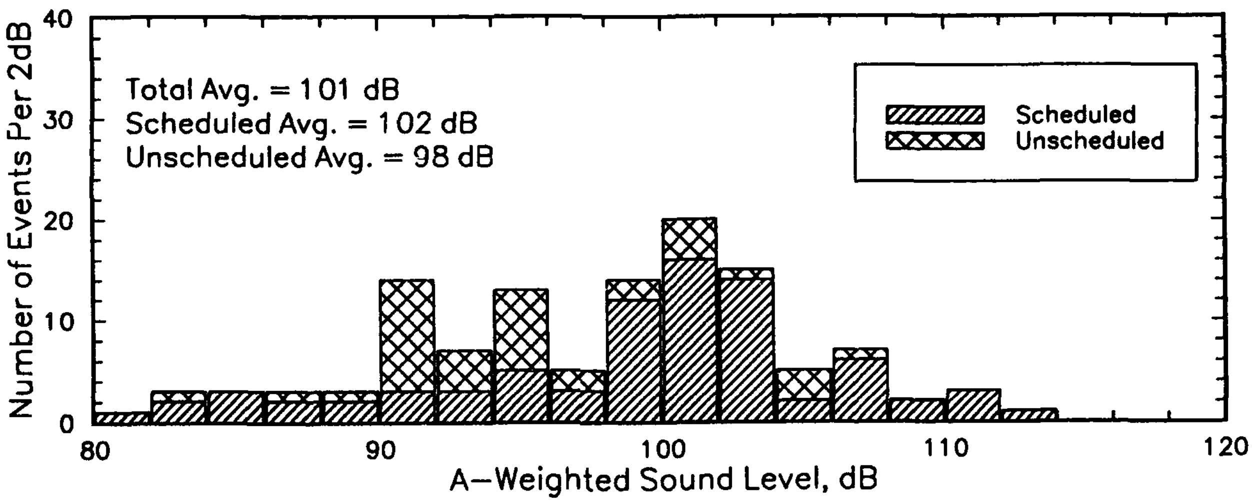


Figure 19. VR-223 Total Events at Each Site.



(a) Distribution of Highest SEL for Each Event.



(b) Distribution of Highest Maximum Level for Each Event.

Figure 20. Distribution of Event Sound Levels, VR-223.

translates into an average altitude of operation of 400 feet. Figure 20(b) is the distribution of maximum levels per 2 dB which has an energy average of 101.3 dB.

As with the previous MTR, the average levels for unscheduled events are much lower than the scheduled event average. This is once again due to A-10 activity.

4.3.3 VR-087 Measurement Results

The distribution for VR-087, shown in Figure 21, has a mean of -0.82 nautical mile and a standard deviation of 2.45 nautical miles. The offset of the mean, in this case, may be due to the location of the I-95/Route 527 intersection 1.3 nautical miles north of the centerline. The aircraft operating on the route may use this as a navigation landmark, thus shifting the center of operations toward it. The cumulative probability distribution for VR-087 is shown in Figure 22. The data follows the straight line of the ideal normal distribution fairly well except near the north end of the route. The total exceedances measured at each site are show in Figure 23.

The distribution of sound exposure levels for VR-087 is shown in Figure 24(a). The energy average for this distribution is 101.5 dB which coincides with an average altitude of operation of 600 feet. The distribution of event maximum levels per 2 dB is shown in Figure 24(b). The corresponding energy average is 95.8 dB.

4.3.4 VR-088 Measurement Results

The distribution of events along VR-088, shown in Figure 25, has a mean of -0.84 nautical mile and a standard deviation of 3.63 nautical miles. Notice that the data in Figure 25 does not appear normal in shape, but appears to be uniform across the route. This is probably due to the low number of events recorded on the route, and the reliability of the standard deviation is questionable. The offset of the mean may be due to the presence of a small town directly under the route centerline along the measurement array which the aircraft avoided to the north. The cumulative probability distribution for VR-088 is shown in Figure 26. Even though the event distribution plot in Figure 25 does not appear Gaussian, the data

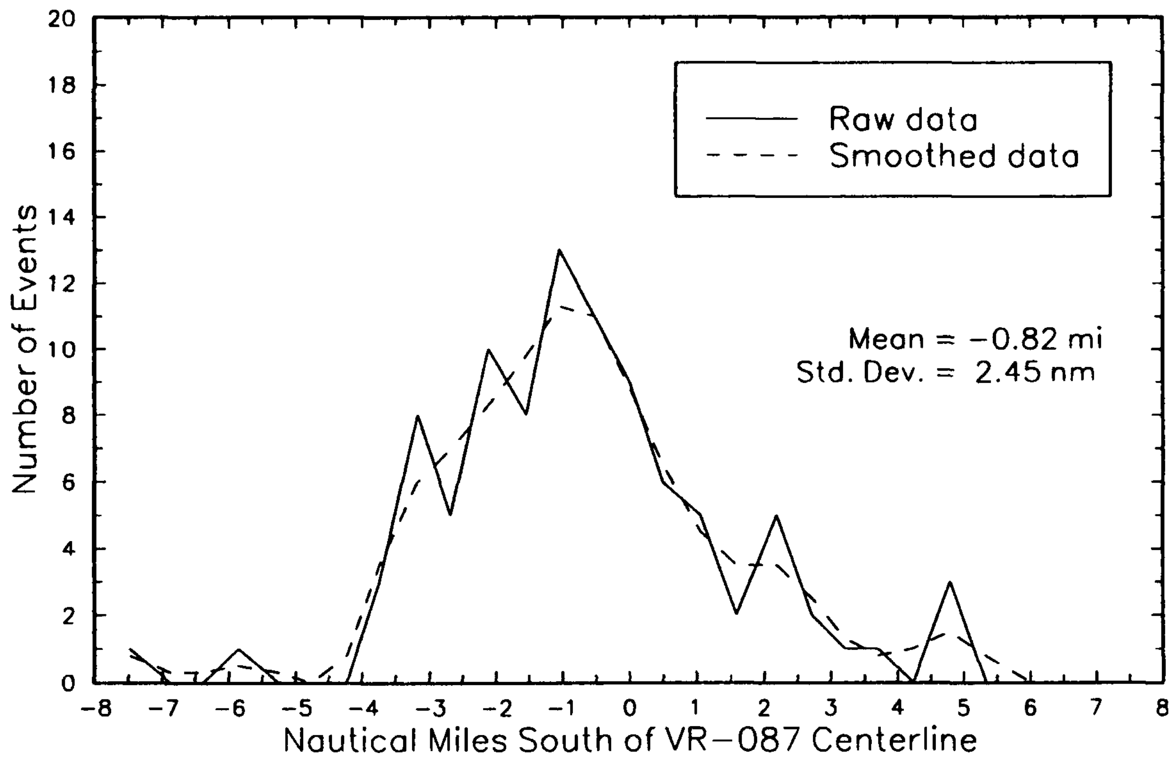


Figure 21. VR-087 Event Distribution.

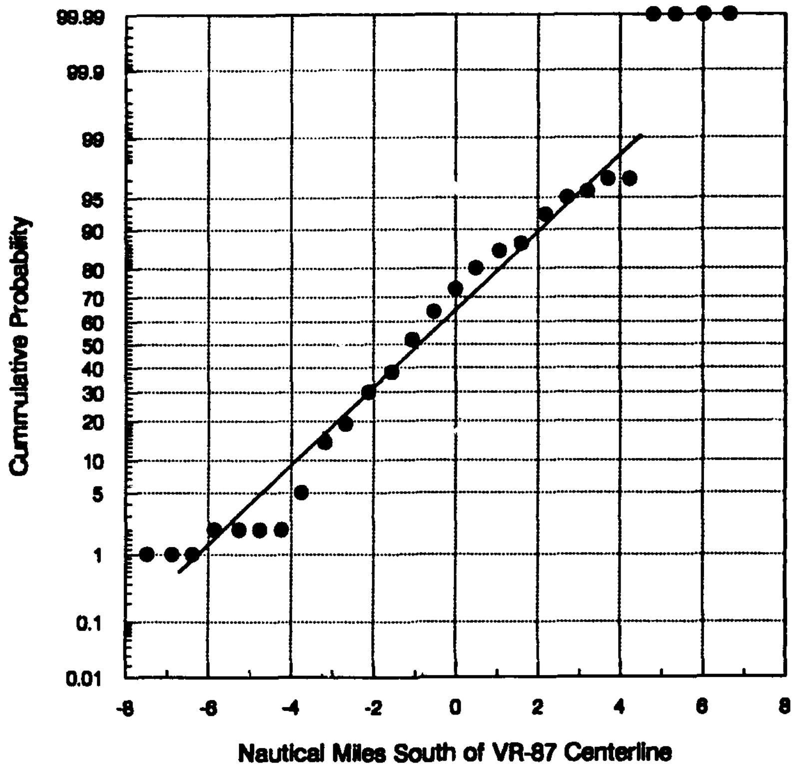


Figure 22. VR-087 Event Cumulative Probability Distribution.

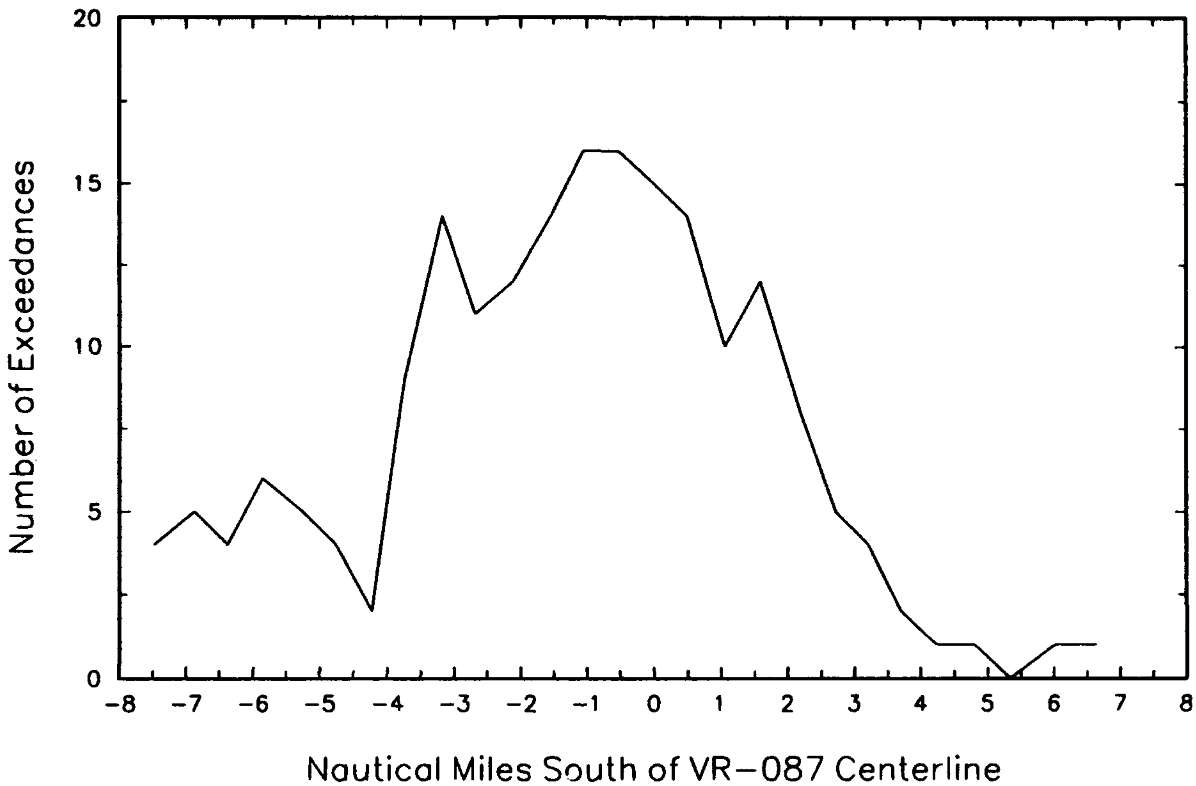
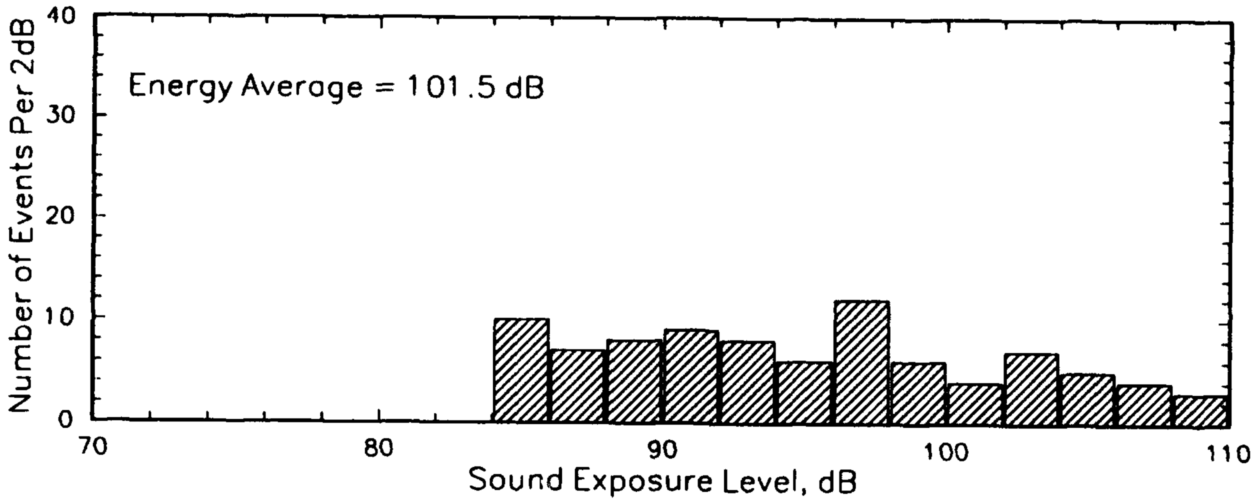
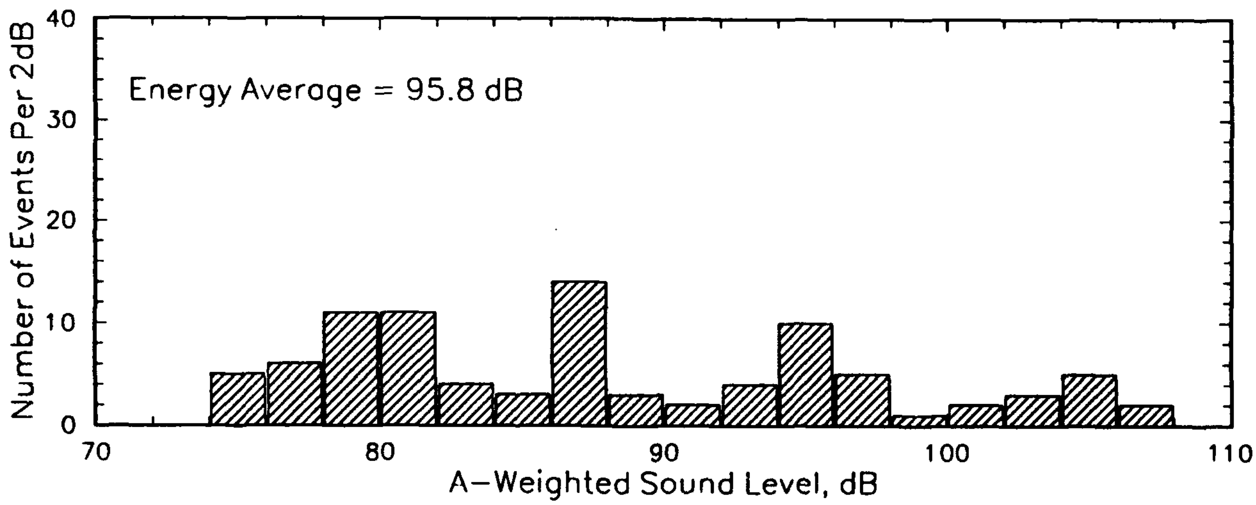


Figure 23. VR-087 Total Events at Each Site.



(a) Distribution of Highest SEL for Each Event.



(b) Distribution of Highest Maximum Level for Each Event.

Figure 24. Distribution of Event Sound Levels, VR-087.

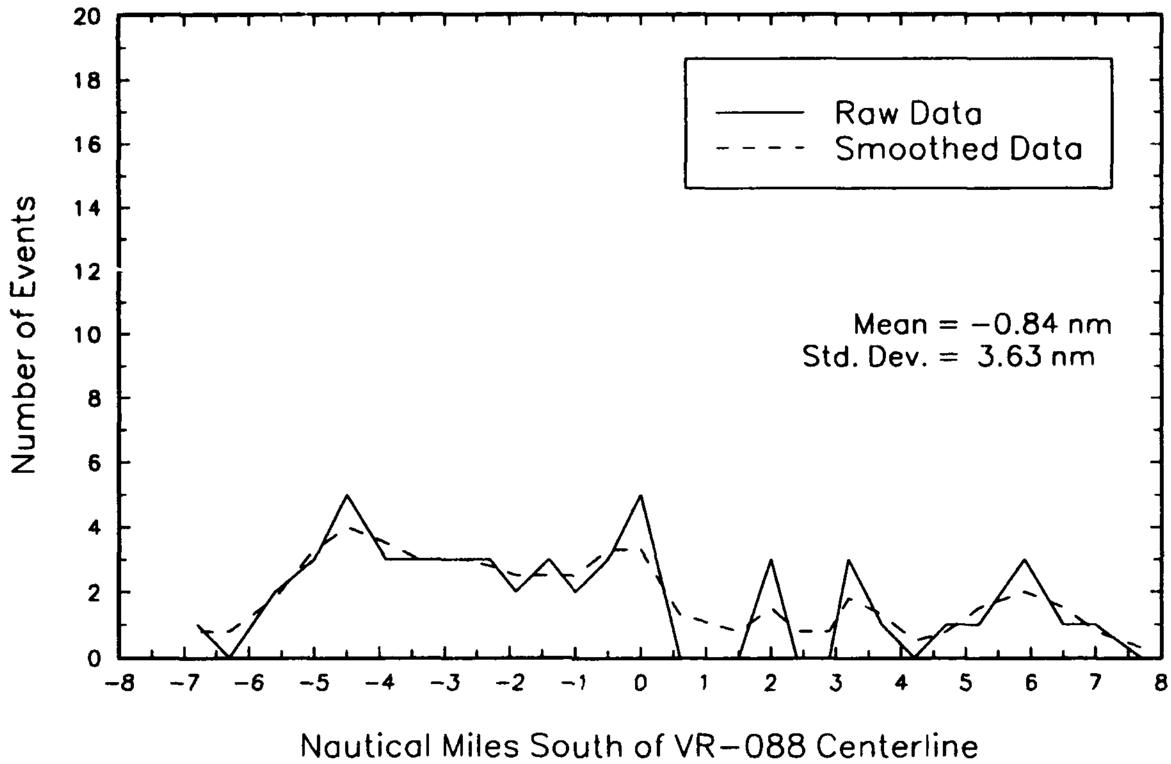


Figure 25. VR-088 Event Distribution.

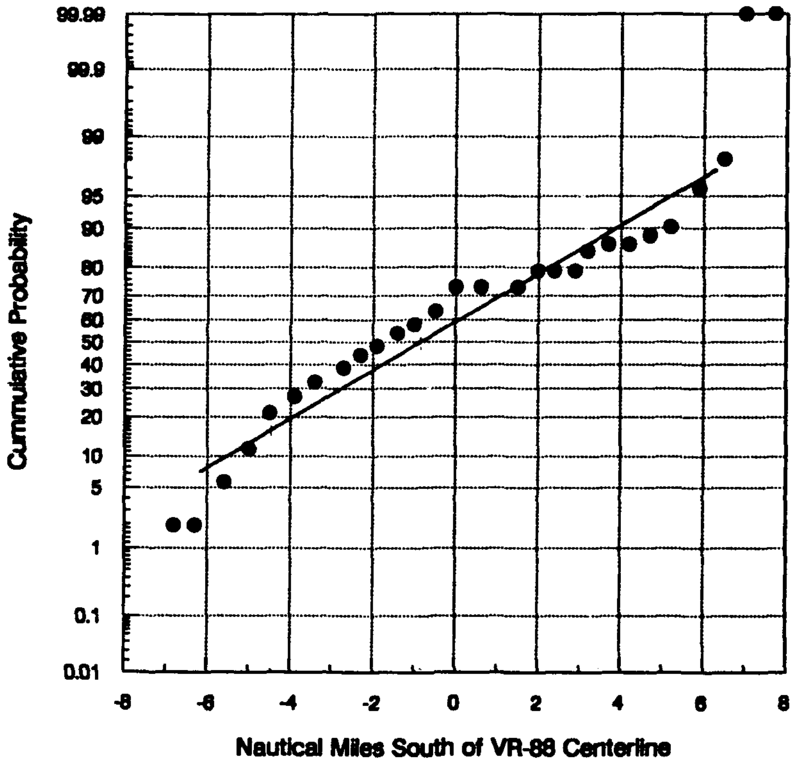


Figure 26. VR-088 Event Cumulative Probability Distribution.

does follow the ideal normal distribution straight line over most of the central part of the route. The total number of exceedances measured at each site is shown in Figure 27.

The distribution of event SEL per 2 dB is shown in Figure 28(a). This distribution has an energy average of 101.9 dB. Since all aircraft operating along VR-088 were F-16s, this corresponds to an average altitude of operation of 500 feet. Figure 28(b) shows the distribution of event maximum levels per 2 dB increment. This distribution has an energy average of 97.1 dB.

4.3.5 VR-1074 Measurement Results

The event distribution on VR-1074 as shown in Figure 29 has a mean of 0.15 nm and a standard deviation of 1.75 nm. Although the offset of the distribution mean is small, it is consistent with the description of operations provided by the scheduling officer at Seymore-Johnson AFB. The presence of two radio towers near the measurement array on the western side of the route forced operations east of the route centerline. The cumulative probability distribution for VR-1074 measurements is shown in Figure 30. The data follows the ideal normal distribution straight line extremely well. Figure 30 contains the total exceedances measured at each site.

The distribution of event SEL per 2 dB increment is shown in Figure 32(a). This distribution has an energy average of 108.2 dB. This corresponds to an average altitude of operation of 500 feet for the proportionate number of F-15s, AV-8s, and A-6s operating on the route. Figure 32(b) shows the distribution of event maximum levels per 2 dB interval. This distribution has an energy average of 105.2 dB.

The distributions for scheduled and unscheduled events are split in Figures 32(a) and (b). As before, the average levels for unscheduled events are lower than those for scheduled events.

4.4 Noise Levels and ROUTEMAP Comparison

The primary purpose of this study is to verify and/or improve the current version of the ROUTEMAP noise modeling program. It has already been

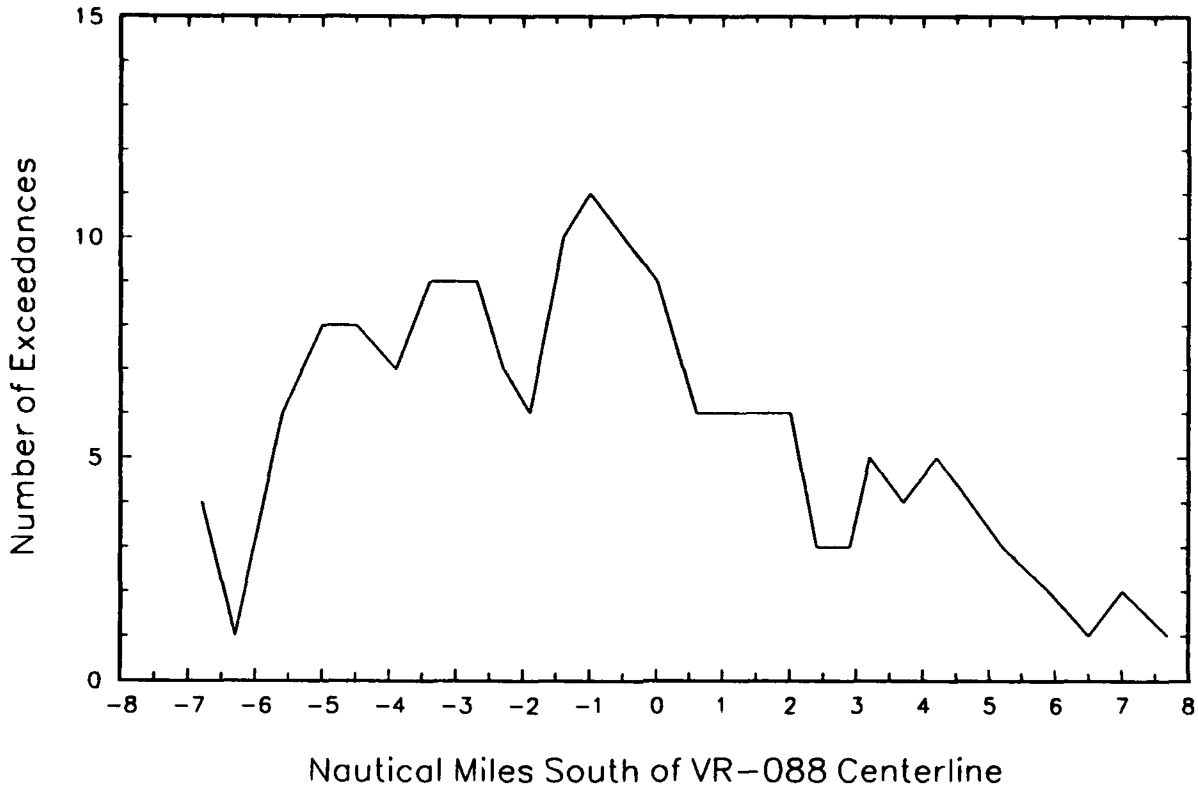
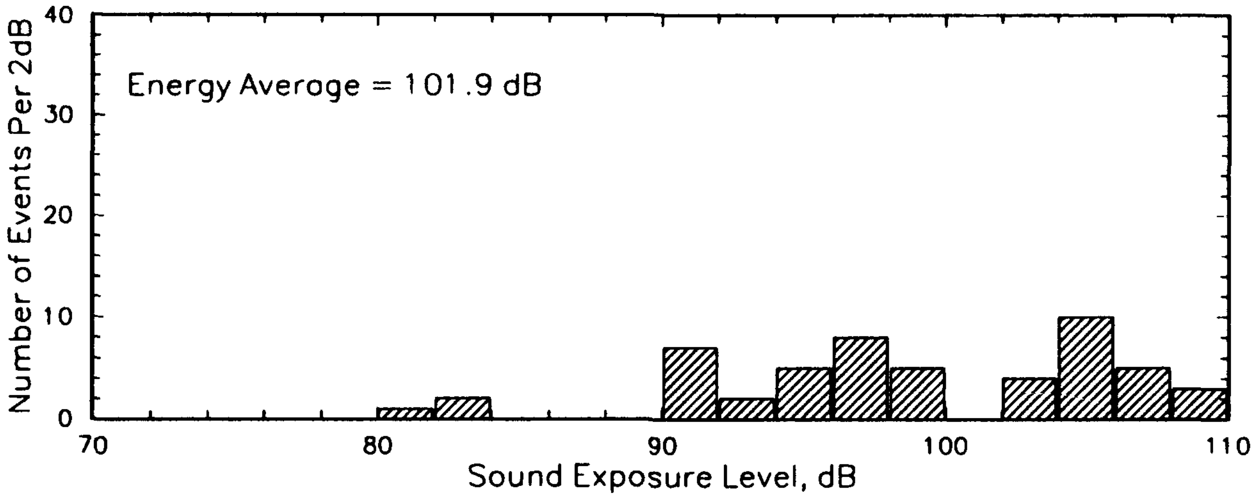
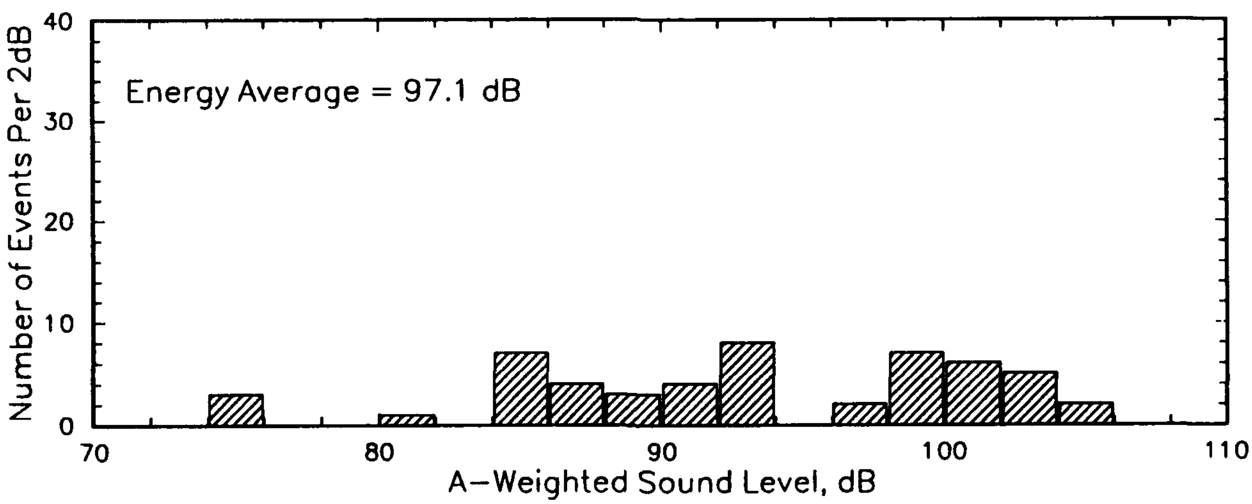


Figure 27. VR-088 Total Events at Each Site.



(a) **Distribution of Highest SEL for Each Event.**



(b) **Distribution of Highest Maximum Level for Each Event.**

Figure 28. Distribution of Event Sound Levels, VR-088.

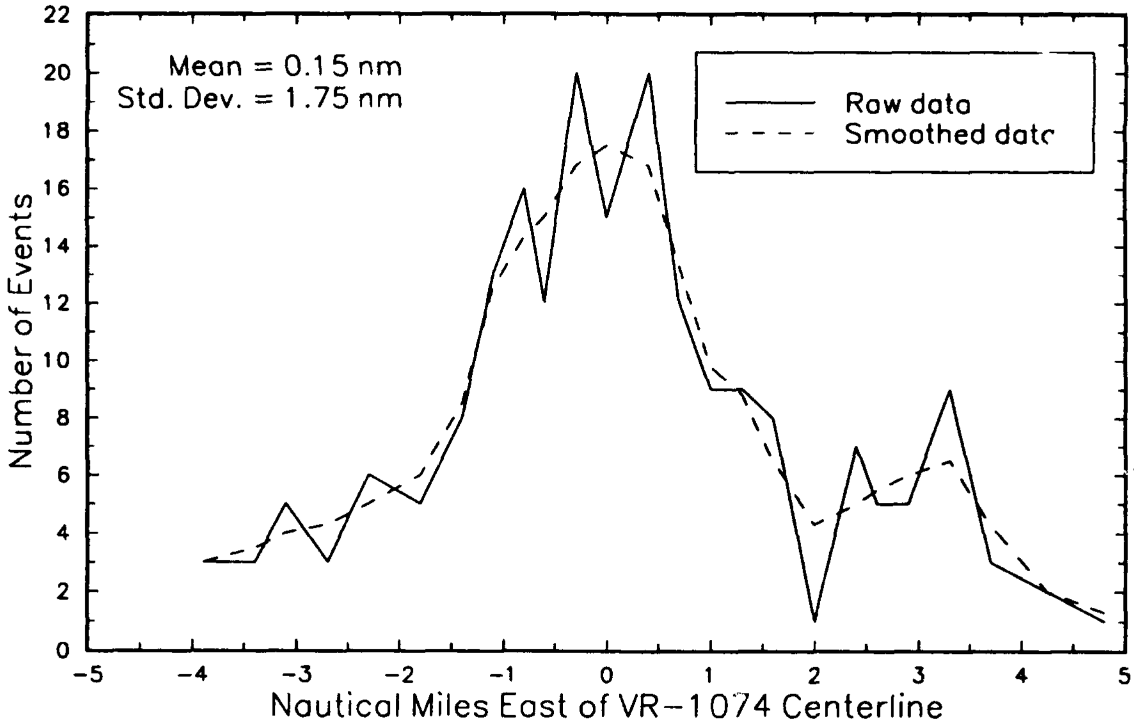


Figure 29. VR-1074 Event Distribution.

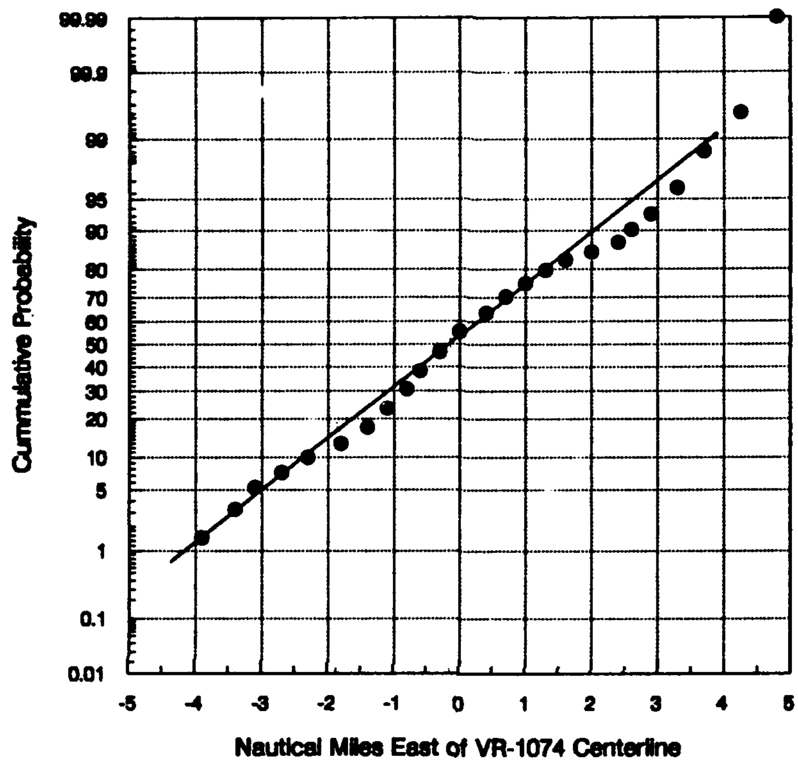


Figure 30. VR-1074 Event Cumulative Probability Distribution.

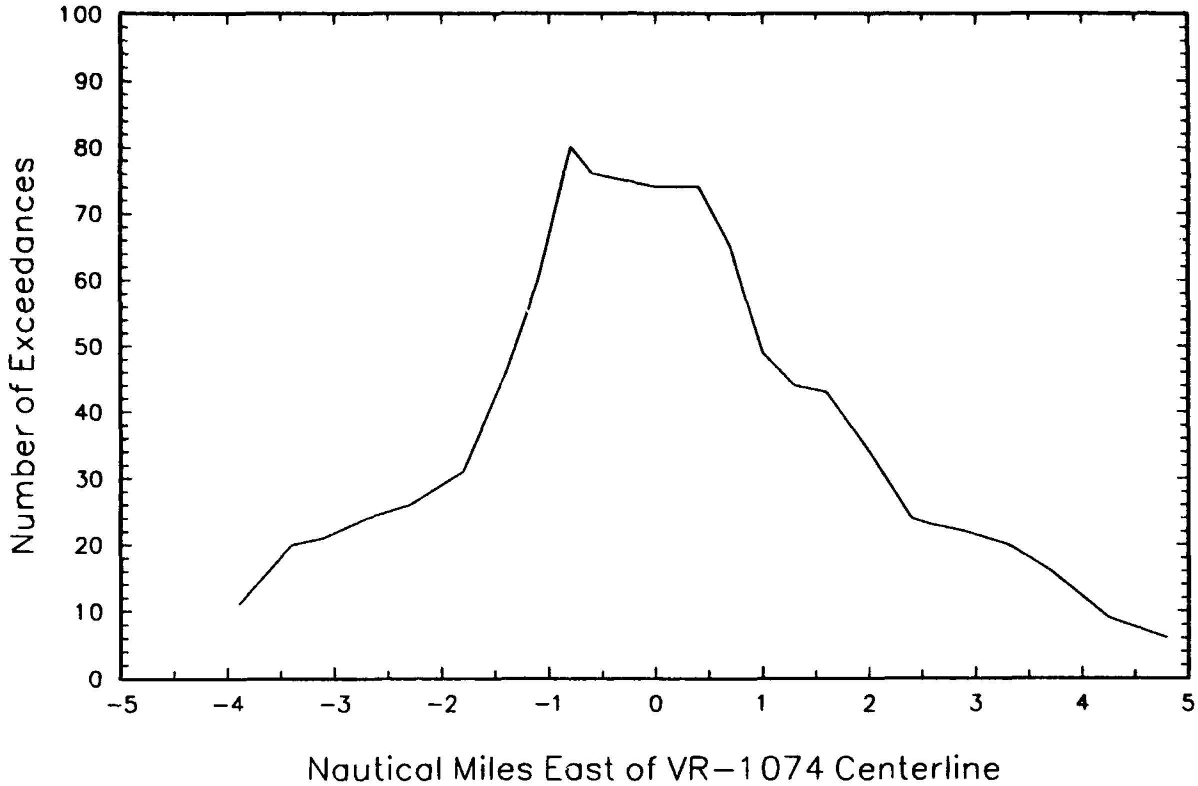
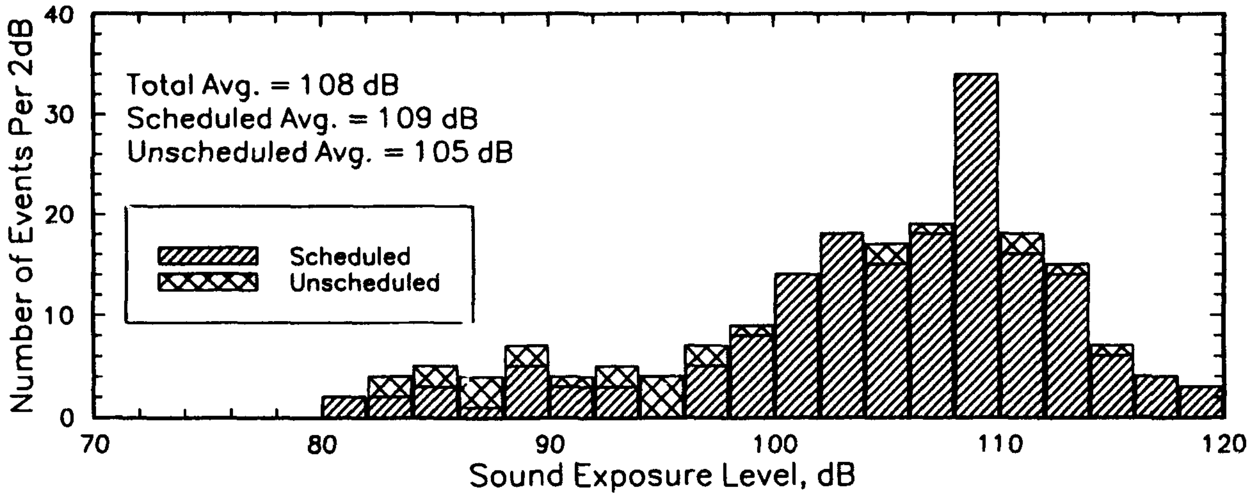
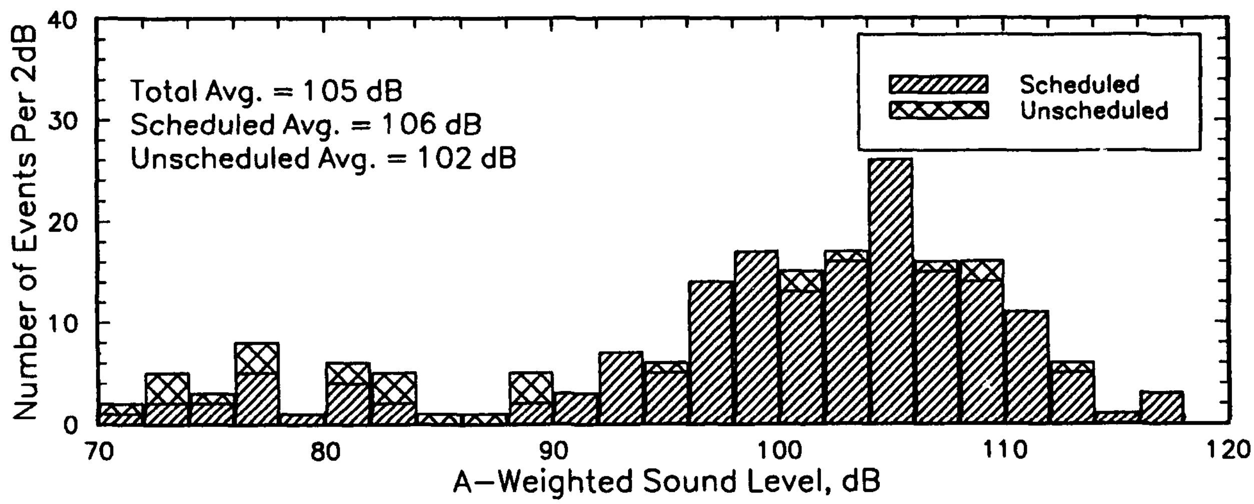


Figure 31. VR-1074 Total Events at Each Site.



(a) **Distribution of Highest SEL for Each Event.**



(b) **Distribution of Highest Maximum Level for Each Event.**

Figure 32. Distribution of Event Sound Levels, VR-1074.

demonstrated that the noise levels associated with individual aircraft which ROUTEMAP employs are satisfactory,[2,4] and the current results are fully consistent with these data. Measurements performed in previous studies support the representation of the distribution of flights across an MTR as Gaussian.[2,4] This representation has been further supported by the results of this study. The last parameter of ROUTEMAP to be investigated is the current basis for selecting a standard deviation.

In order to run ROUTEMAP for a specific MTR, several parameters must be specified including: aircraft type, flight altitude, speed, power setting, number of operations per month, and the standard deviation of the lateral aircraft distribution. The aircraft type, flight altitude, speed, power setting, and number of monthly operations can be obtained from historical scheduling data. Selection of the standard deviation, as specified in the current version* of ROUTEMAP,[5] is based on the following rules:[2,4]

- SAC operations on IRs always have a standard deviation of 0.45 nm (0.5 statute mile). This small deviation is due to the precision of instrument navigation.

- On TAC VRs, operations following a single track (either the official route segment coordinates or locally designated "delta points") will have a standard deviation of 1.1 nm (1.25 statute miles). This wider distribution is due to multi-ship formations and the less precise nature of visual navigation.

- On wider TAC VRs, it is common to have several tracks, particularly if no one visual reference is dominant. If the tracks are known, each is modeled with a standard deviation of 1.1 nm.

- If it is expected that a TAC VR has multiple tracks, but the actual track are not known, then operations are modeled as a single track with a standard deviation of 2.2 nm (2.5 statute miles).

These three standard deviations are built into ROUTEMAP 1.0, but users can specify other values.

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* Version 1.0.

During preparation of environmental assessments which involve a number of routes, it is often difficult to obtain firm information as to detailed track structure. It is therefore common to select standard deviations based on route width. This is somewhat of a judgment call, but is reasonable since it is expected that the added space available in wider routes would be used. One set of rules[9] is the following:

W < 2 nm	Std. Dev. = 0.45 nm
2 nm < W < 6 nm	Std. Dev. = 1.1 nm
6 nm < W	Std. Dev. = 2.2 nm

where W is the width of the route in nautical miles.

This rule assumes that routes wider than 6 nm will have multiple tracks. Deviation is small for very narrow routes so as to remain within the route boundary. It is questionable, however, whether TAC's multi-ship formations navigating visually can have a standard deviation of 0.45 nm. Operations on VR-223, where the effective route width was 3 nautical miles, had a standard deviation of 0.95 nm, and some operations spilled over the route boundary.

ROUTEMAP has been applied to the five current MTRs, selecting the standard deviation based on the above rule. The aircraft operating parameters were selected based on information provided by operations personnel at the Air Force Bases involved. The number of operations were based on the total number of sorties detected by the monitoring arrays. The proportionate number of different aircraft for each route was determined by the number of aircraft listed in the schedule. For example, if half of the scheduled aircraft were F-15s and the other half F-16s, then half of the total detected sorties was assigned to each aircraft type. It was assumed in the ROUTEMAP models that the altitude of operation for all aircraft was as determined from the single-event SEL distribution (Figures 16(a), 20(a), 24(a), 28(a), and 32(a)).

Figures 33 through 37 show the measured L_{dn} levels along with the levels as predicted by ROUTEMAP for similar operations. The L_{dn} (which is equivalent to L_{eq} since no night operations were detected) represents the energy average, over the measurement period, of low-altitude aircraft noise. L_{dn} includes all events which exceeded the monitor threshold at each site due to aircraft overflights.

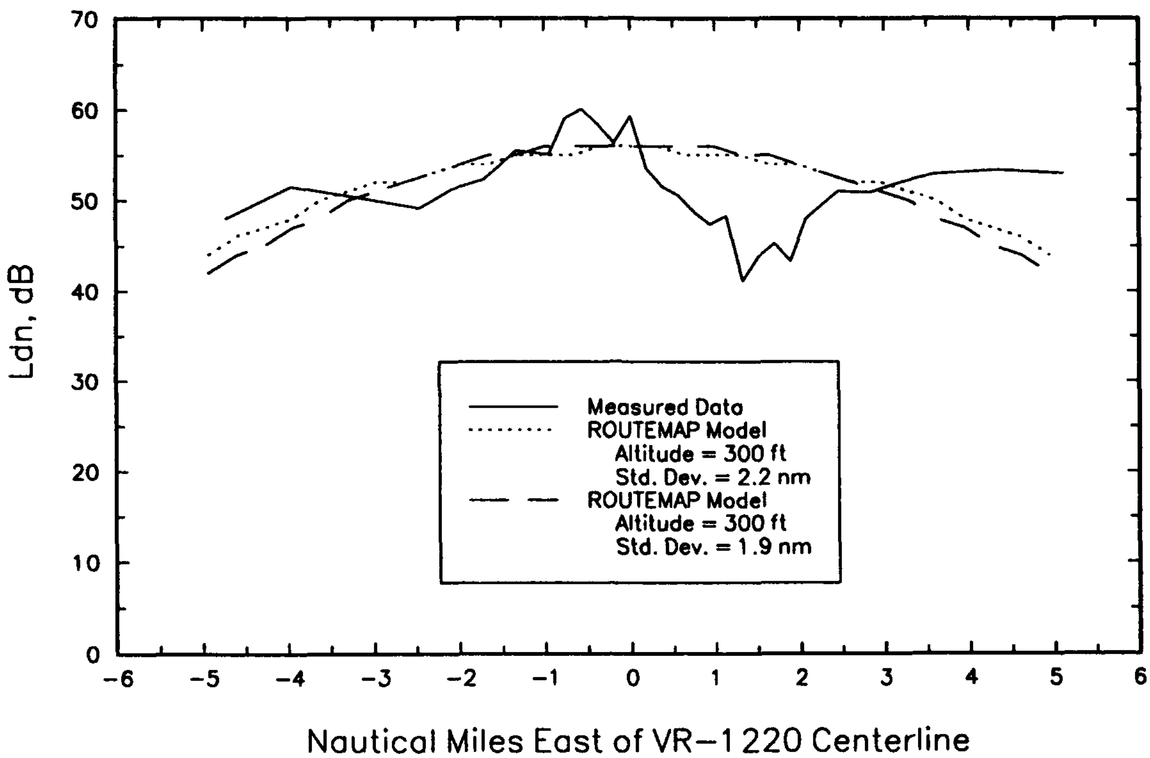

Figure 33. VR-1220 Measured and Predicted L_{dn}.

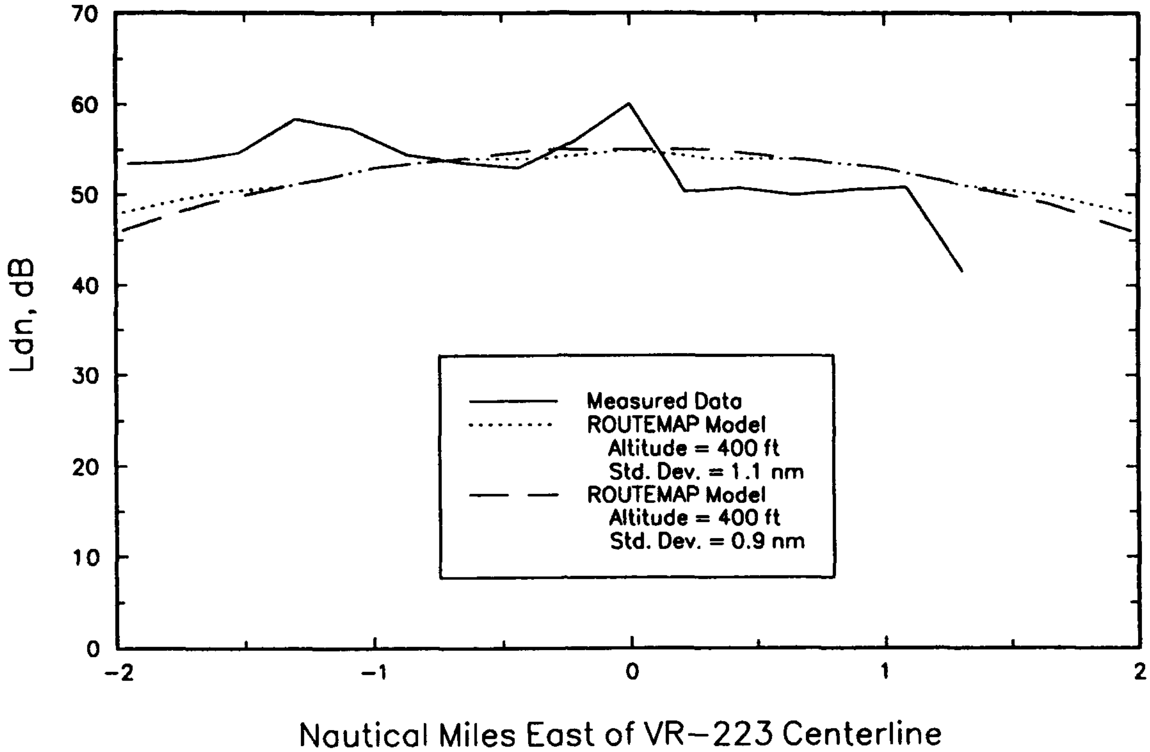

Figure 34. VR-223 Measured and Predicted L_{dn}.

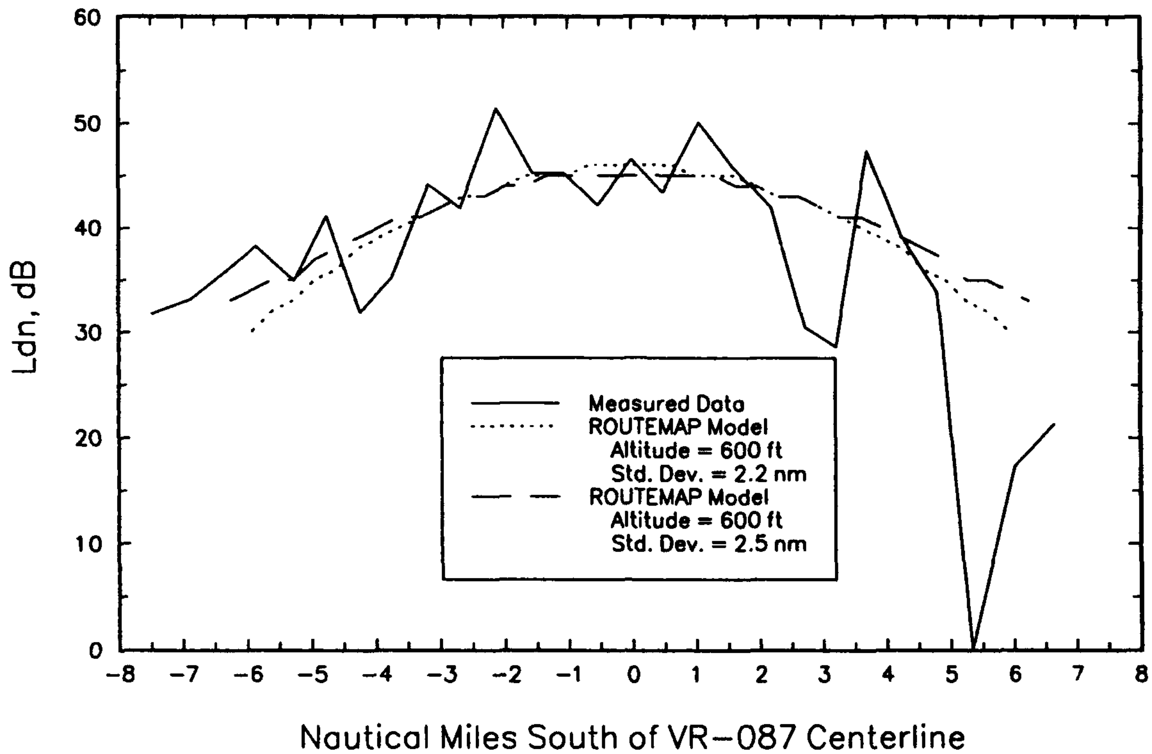

Figure 35. VR-087 Measured and Predicted L_{dn}.

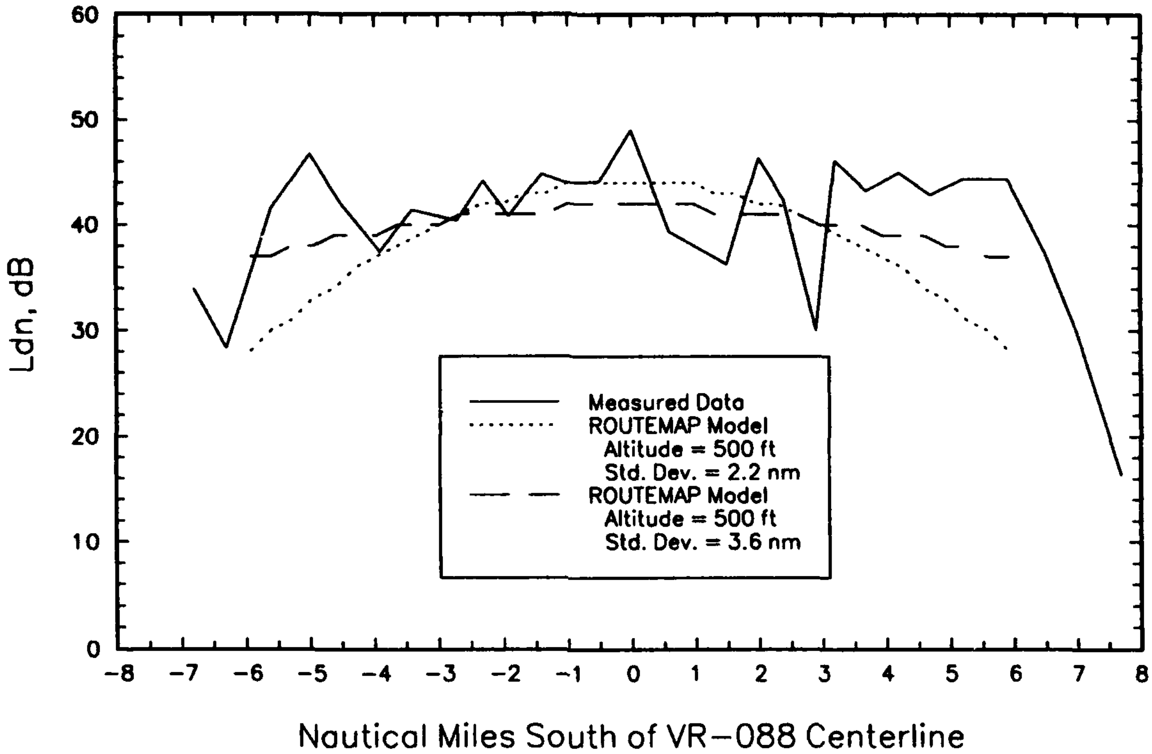

Figure 36. VR-088 Measured and Predicted L_{dn}.

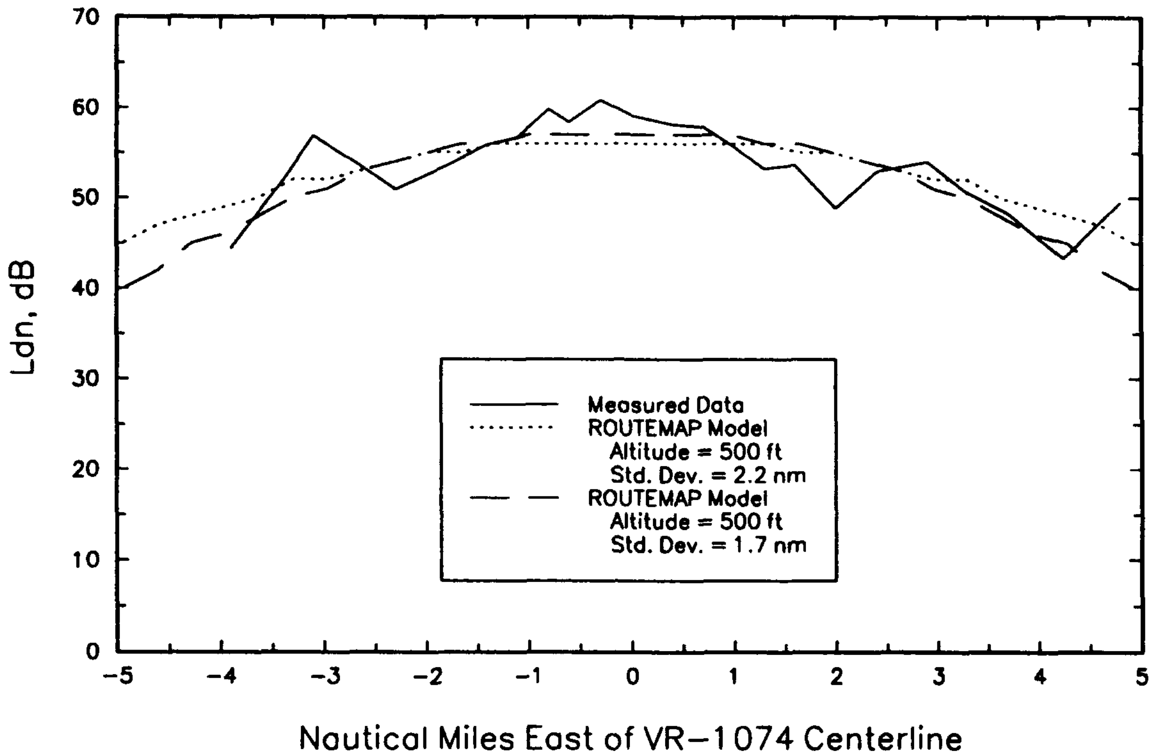

Figure 37. VR-1074 Measured and Predicted L_{dn}.

Figures 33 through 37 compare the measured levels with ROUTEMAP predictions for two standard deviations: the measured value, and either 1.1 or 2.2 nm, as selected from the above rule. (VR-223 uses 1.1 nm; the others all use 2.2 nm.)

Overall, Figures 33 through 37 show very good agreement. The measured data show local departure from predictions, and considerable site-to-site variation, but this is a consequence of the relatively small statistical samples at each site. The nominal standard deviations provide reasonable agreement, but the measured values (obviously) are better. The question is, whether the rule of using the two nominal values is adequate, or whether there is a more general pattern.

This question is answered in Table 6, which shows the route width, the measured standard deviation, and the ratio between the two, for the five routes measured in this study plus the two previous TAC routes studied in Reference 4. For five of the seven routes, the ratio is very close to 0.17. The other two routes have ratios which are either substantially higher or lower. Note that, while the Reference 9 rule (1.1 or 2.2 nm, based on route width being smaller or larger than 6 nautical miles) is reasonably satisfied by six of the routes, one route (VR-231) is 10 nm wide but has a standard deviation of 1.1 nm.

Table 6

MTR Distribution Summary

MTR	Width (nm)	Measured Std. Dev. (nm)	Std. Dev./ Width
VR-1220	10	1.9	0.19
VR-223	4	0.9	0.23
VR-087	16	2.5	0.16
VR-088	20	3.6	0.18
VR-1074	10	1.7	0.17
VR-231	10	1.1	0.13
VR-1066	13	2.5	0.19

The distinguishing feature of the two routes for which the standard-deviation-to-width ratio is not 0.17, is that they each have a single dominant track. For VR-223, this is forced by the very narrow width. For VR-231, this is forced by

the fact that there were dominant visual references (Big Horn Peak and Little Harquahala Peak, as described in Reference 4) which led to the use of a single track. The other routes are in areas where there are no particular dominant features, and where there can be variety in nominal tracks. Considering that a narrower spread than measured on VR-223 does not seem probable, it appears that the rule set forth in Reference 4 is the correct one: a single nominal track has a standard deviation of 1.1 nm (this is probably not significantly different, in a statistical sense, than the 0.9 nm measured on VR-223), while routes without a dominant track will be utilized in a multi-track manner, with a larger overall spread. Rather than the single value presented in Reference 4, this value is 0.17 (average of the five pertinent values in Table 6) times the route width.

In addition to a revised multi-track standard deviation based on the new measurements, it is reasonable to revise the single-track value to represent both VR-231 (the source of the old value) and the new measurement on VR-223. The average of the two is 1.0 nautical mile. The final result of this study is that the standard deviation is given by:

- 1.0 nautical miles, routes with a single dominant track
- 0.17 times route width, multi-track routes, but not less than 1.0 nm.

The 1.0 nautical mile spread must be regarded as a minimum, so that it will always apply to routes less than 6 nautical miles wide. For wider routes, the 1.0 nm spread will apply when there is a single, obvious, dominant track. For routes where there are multiple tracks, and the locations of the tracks are known, a standard deviation of 1.0 mile should be applied to each track. If the route is wider than 6 nm, and multiple tracks are expected but their locations are not known, a single track with a standard deviation of 0.17 times the route width is used.

The above results were obtained for routes up to 20 nm wide. It is not apparent whether the 0.17 times width rule would apply to routes wider than 20 nm. It is quite possible that a very wide route could be operated as several parallel narrow routes. If a route wider than 20 nm is being analyzed, the route designer must be consulted to determine what operations are expected to be. It is also important, for any route, to establish whether the defined route width

represents the actual usable portion of the route. This was the case for all routes studied here (except for the Tabletop Mountain choke at the VR-223 measurement site), and MTR analysis must be based on the usable route width.

The previous recommendation[4] had been to use a single value of 2.2 nm for nominal multi-track routes. It is seen in Figures 33, 35, and 37 (which represent routes 10 to 16 nm wide) that this single value yields centerline noise levels within 1 dB of those obtained if the actual standard deviation is used. In the overall assessment of airspace actions which involve many routes, it is reasonable to use a single standard deviation of 2.2 nm for routes between 10 and 16 nm wide. It is also reasonable to establish similar average values for other width ranges. In general, variation of the standard deviation by 25 to 30 percent leads to sound level differences of no more than about 1 dB. When analyzing the impact associated with a single specific route, however, the actual standard deviation for that width should be used.

5.0 CONCLUSIONS

Noise measurements were performed on five Military Training Routes including VR-1220 and VR-223 in Arizona, VR-87 and VR-88 in South Carolina, and VR-1074 in North Carolina. The objective of these measurements was to determine the lateral distribution of operations along these routes in order to validate or update the structure of the ROUTEMAP MTR noise modeling program.

It was determined from these measurements that the ROUTEMAP representation of a Gaussian distribution of operations about the route centerline is valid. The operations distributions on all routes studied support this.

It has also been established that the standard deviation of this distribution is dependent on route width, and is 0.17 times the route width. This spread is due to a combination of missions using a variety of nominal tracks and the variation inherent in visual navigation at these high speeds. An exception to this simple relation between route width and dispersion is when a route has only one dominant nominal track. This was observed at a choke point in one route studied here, and was observed on a previously studied route where route usage was dominated by prominent isolated visual references. The standard deviation about a single track has been determined to be one nautical mile.

It is recommended that ROUTEMAP be revised to specify standard deviations in nautical miles, rather than statute miles, and that the following standard deviations be used:

- When the actual nominal tracks are known, use a standard deviation of 1.0 nm for operations on each track.

- For routes between 6 and 20 nm wide, and it is expected that there will be multiple tracks but the actual tracks are not known, use a standard deviation of 0.17 times route width.

- For routes less than 6 nm wide, assume there will be a single track with standard deviation of 1.0 nm.

- For routes wider than 20 nm, it is necessary to establish how the route is used, then model it as either one wide route (extrapolating the 0.17-times-width rule) or as a set of narrower routes.

When many routes are being analyzed for overall assessment of a proposed action, it is reasonable to use approximate values of the standard deviation, so long as these are within 25 to 30 percent of the value from the above rules. If a single route is being analyzed, the above rules should be followed.

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